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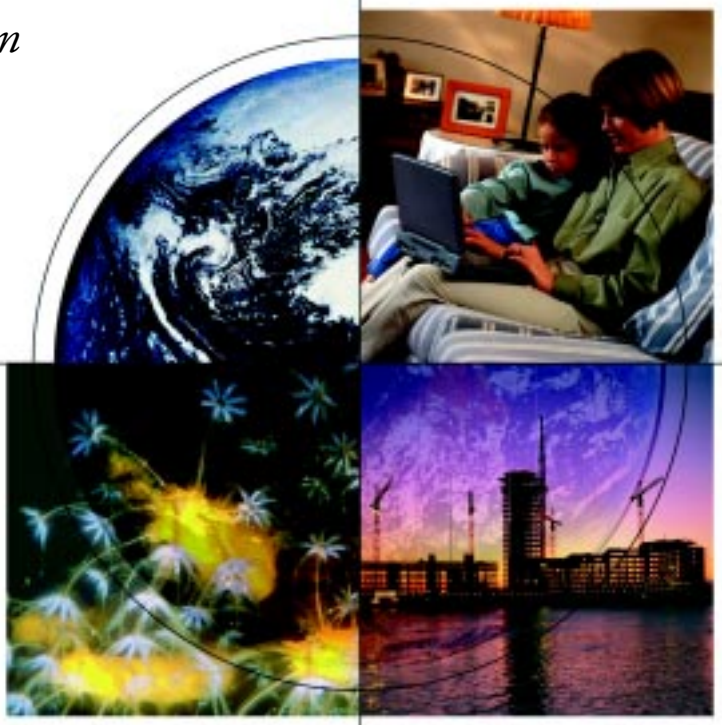
FETC

F O C U S

The children and the flowers are a promise of the future and a blessing for today . . .



Protecting the Promise

U.S. DEPARTMENT OF ENERGY • OFFICE OF FOSSIL ENERGY
FEDERAL ENERGY TECHNOLOGY CENTER

Rita A. Bajura
Director, FETC

Welcome From The Director

Economic growth, a clean, healthy environment, and peace are universally held goals of humanity. Together they represent a Promise of the Future that we seek to pass on to our progeny. The Federal Energy Technology Center (FETC) focuses on a suite of advanced energy technologies, environmental programs, and related services that help protect this promise.

All human activities have an effect on the environment. The challenge is to ensure that the activities which maintain or enhance our standard of living are balanced with a concern for the environment. We must manage the use of our resources to allow future generations the opportunity to achieve their goals. It is a difficult challenge for the world and for the U.S. At FETC, we depend on the dual pillars of Sustainable Economic Development and Ecosystem Management to help our country achieve that delicate balance.

In developing advanced power systems, we seek to ***improve efficiency*** so that fossil resources will be available for future generations and pollutant emissions will be minimized. We aim for ***lower cost*** so that fewer materials will be needed to build power plants and so that more societies can have access to the benefits of clean, affordable electric power. Simultaneously, we ***reduce pollutants*** so that the power required for world economic development will not result in environmental degradation.

Our ecosystem is an intricate, interconnected web of living things and the physical environment that surrounds them. Ecosystem Management considers all the impacts on an ecosystem and seeks solutions that have the best overall outcome for the ecosystem and the human community.

This second issue of *FETC Focus* emphasizes our environmental programs, which include remediation of sites contaminated in the nuclear weapons program as well as environmental solutions for clean electric power. We rely on advanced technologies that offer more effective, efficient, and economical methods for cleaning up radioactive and other hazardous materials from contaminated areas and buildings, and for the generation of clean power.

FETC's approach to environmental solutions is collaborative—industry, academia, private parties, and local, state, tribal, and federal agencies working together as partners. We seek to integrate ecological, social, economic, and institutional perspectives in developing environmental solutions. We insist that these solutions are real ones and do not merely convert a water problem into a soil problem, for example.

In this global age with increasing human demands and challenges on the environment, sustainable economic development is a necessity. FETC is determined to meet these challenges with advanced energy and environmental solutions that we and future generations can live with and be proud of.

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About the Cover

For the children and the flowers are my sisters and my brothers. . .They're a promise of the future and a blessing for today. . .Come and stand beside us, we can find a better way. John Denver, "Rhymes and Reasons" © 1969, Cherry Lane Music Co.

FETC invites you to join us in finding a better way—to protect the promise of the future.

Carl O. Bauer
Associate Director

Office of Product Management for Environmental Management

Protecting the Promise of the Future

We are finding **a better way:** *a better way* to prevent damage to our environment; *a better way* to clean up unresolved problems resulting from more than a century of industrial growth. The programs and products of the Federal Energy Technology Center (FETC) focus on finding a better way to protect the promise of the future.

FETC's goal is to find energy and environmental solutions that yield *sustainable economic development* for the U.S. This means we balance our research into better, more efficient, and more cost-effective technologies for advanced power generation with an equivalent level of research into better, more efficient, and more cost-effective ways of preventing or mitigating damage to the environment.

Our approach to environmental solutions is collaborative—industry, academia, private parties, and local, state, tribal, and federal agencies work together as partners—and our initiatives integrate ecological, socio-economic, and institutional perspectives. But we also insist that any solutions must be *real* solutions: we don't want a water solution to become a soil problem, for example.

We can describe our environmental initiatives in terms of (1) the environmental parts of an ecosystem: air, water, and soil; or (2) the major problem areas being addressed: prevention, compliance, and cleanup. However, FETC's environmental initiatives cross the boundaries of these categories (i.e., a single project could involve both soil and water, or cleanup and compliance). Furthermore, FETC is dynamic; our initiatives change to meet the changing goals and needs of the United States.

Our current environmental efforts are in three primary focus areas:

1. Environmental Management—technology for remediating the cold-war legacy wastes.

FETC uses free-market competition and partnerships with public- and private-sector entities to breed innovation and keep prices for energy and environmental technologies at a reasonable level.

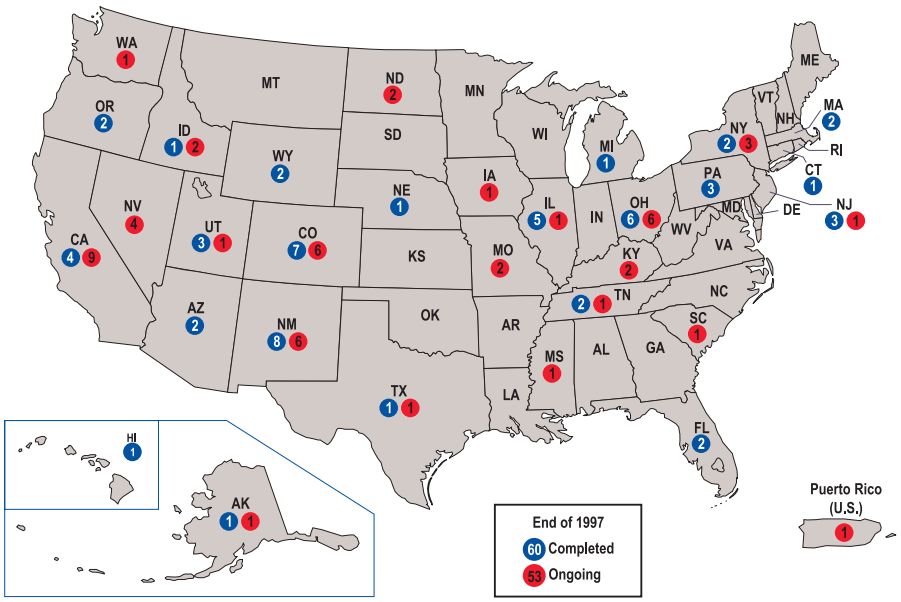
2. Fossil Energy—technologies for cleaner and more efficient use of fossil fuels.
3. Clean Water—improved ways of protecting our water resources.

Some of our environmental programs and products are highlighted in articles in this issue of *FETC Focus*.

Environmental Management—Reducing DOE's Mortgage

We live in a safer world today, largely thanks to the end of the Cold War. But we still have a massive nuclear-weapons legacy to deal with. In 1989, DOE established the Environmental Restoration and Waste Management Program, now called the Environmental Management (EM) Program, to deal with this legacy. The DOE complex contains thousands of contaminated areas and buildings, and large volumes of waste and special nuclear materials requiring treatment, stabilization, and disposal. It is the largest environmental stewardship program in the world.

DOE Environmental Restoration Sites by State



DOE recently estimated that the total cost of the program will be $147 billion over a 73-year period—a long and hefty mortgage! By the beginning of 1998, 60 of 113 contaminated sites had been cleaned up under the EM Program. The goal is to complete the cleanup of 90 percent of the 53 remaining sites by 2006 at a cost of about $57 billion. However, completing the cleanup does not end DOE's responsibility. In most cases, DOE will continue long-term surveillance and monitoring activities to ensure that human health and the environment are protected. The remaining $90 billion is to be expended from 2007 to 2070, and includes these long-term activities.

Industry and University Programs: The U.S. economy is built on the premise that free-market competition breeds innovation and keeps prices at a reasonable level. Why not bring this same thinking to federally sponsored research? FETC is using government contracting mechanisms

and competitive procurements to do just that.

FETC partners with public- and private-sector entities under the Industry and University Programs (IUP) to assist them in developing their technologies through full-scale demonstration at DOE sites. This partnering ensures that industry, including small businesses, can compete within the DOE market to deploy innovative, cost-effective environmental solutions—solutions that reduce the costs and the health and safety risks associated with cleanup activities. This partnering process, and the phased nature of the contracts, also ensures that projects are effectively managed. Projects are not carried forward to the next stage or are redirected as the technology matures and moves toward commercial application. IUP projects cross-cut several other EM programs, acting as a catalyst for demonstrating environmental solutions.

FETC estimates that cost savings of $800 million to $2.4 billion could be realized by widespread use of the initial 15 technologies that have been implemented at DOE sites. These cost savings are based on uncertain market projections and are revised as DOE continues to define market opportunities for cleanup technologies and services. Nonetheless, the current estimate represents a 4:1 to an 11:1 return to the government for the $209 million investment to date in this technology development program.

Deactivation and Decommissioning: FETC is actively searching for solutions to reduce the DOE mortgage of radiologically contaminated surplus facilities. The emphasis is on demonstrating and implementing technologies that are lower in cost, require less labor, reduce exposure of personnel to radioactive and other hazardous materials, improve worker safety, and generate lower quantities of waste materials. Some of the technologies are already available in the private sector, but have yet to be evaluated and deployed against the problems within the DOE complex; others are innovative solutions developed through deactivation and decommissioning (D&D) research.

The highlight of the research is a series of large-scale demonstration and deployment projects (LSDDPs). New or improved technologies are demonstrated at full-scale beside competing baseline technologies; end users then compare the cost and performance data to determine whether or not to use the new technologies. Three facilities were chosen in January 1996 to host the first

LSDDPs in Illinois, Ohio, and Washington State. A total of 24 new technologies, representing over 80 new deployments, were demonstrated at these LSDDPs by the end of 1998.

Fossil Energy—Cleaner Use of Fossil Fuels

The future strength and stability of the U.S. economy depend on the continued availability of affordable electricity and energy. The ample supply of fossil fuels in the U.S. makes them a cost-effective energy source, but significant environmental issues must be addressed for the U.S. to continue to use fossil fuels, particularly coal, to generate electricity. Deregulation and restructuring in the electricity industry are forcing electric utilities to maximize the utilization, reduce the operating costs, and extend the lifetimes of existing coal-fired power plants. Efficient, cost-effective pollution control technologies are key to maintaining the viability of power generation systems well into the next century.

Fossil energy environmental initiatives focus on:

- ***Demonstrating*** technologies that increase the utilization of high-volume coal-combustion by-products, such as fly ash and scrubber sludge, as well as ***creating*** high-value uses of solid materials generated by advanced coal combustion systems by 2000, ***facilitating*** acceptance of the effective use of coal by-products as a "common business practice."
- ***Offsetting*** all net growth in greenhouse gas (GHG) emissions in the U.S. after 2010 by ***developing*** a set of sequestration options, with GHG emissions reductions to begin in 2015; and ***developing*** even more cost-effective technologies to capture and sequester GHG emissions by 2020.

What is...?

Nonpoint Source Pollution? Nonpoint source pollution results from activities that physically disturb the land or water, such as agriculture, forestry, mining, oil and gas development, grazing, or construction. Urban runoff also contributes. Water from precipitation or irrigation picks up pollutants from non-specific points or sources and deposits them in streams, lakes, rivers, or coastal waters—or introduces them into groundwater. A pipe coming directly from a sewage disposal plant is point source pollution; acid mine drainage is nonpoint source pollution.

$PM_{2.5}$? $PM_{2.5}$ are "fine" particulates—particles with an aerodynamic diameters of 2.5 micrometers (µm) or less. (The average human hair has a diameter of 80 to 100 µm.) They are a special health concern because their small size allows them to penetrate and lodge deeply in the lungs. $PM_{2.5}$ have been shown to contribute to respiratory symptoms and disease, decreased lung function, and premature death.

SCR? Selective catalytic reduction, or SCR, is using a catalyst to convert oxides of nitrogen into nitrogen gas (N_2), which is harmless, and water. Ammonia (NH_3) acts as the reducing agent and is injected into a flue gas containing NO_X, reducing the NO_X to N_2. The catalyst (usually a metal oxide) is contained in either a honeycomb or plate structure and operates at a temperature of about 700°F. Because of the large volumes of flue gas that need to be treated, the catalyst structure is extremely large. The SCR process is selective because the added ammonia selectively reduces NO_X to N_2. In the non-selective catalytic reduction (NSCR) process (such as the emission control system in your auto), the NO_X reacts catalytically with carbon monoxide to produce oxygen, N_2, and CO_2.

- ***Developing*** post-combustion nitrogen oxides (NO_X) control technologies that can meet emissions standards for ozone mitigation at a cost 25 to 50 percent less than available with today's technology—selective catalytic reduction or SCR—by 2003; and ***demonstrating*** particulate control technology that can reduce fine particle emissions by 99.9 percent, especially extremely small particles with diameters of 0.1 to 1.0 micrometers (μm), and ***providing*** a suite of mercury-control technologies that can remove all forms of mercury from coal-combustion flue gas by 2005.

Coal Combustion By-Products (CCBs): By-products result when coal is burned. Some of these by-products are environmentally deleterious but can be turned into useful and commercial products. FETC is developing or improving technologies that minimize or abate the adverse environmental impacts of CCBs and produce economical high-volume markets for CCBs. The ultimate goal is to reduce the costs of complying with solid waste regulations, and to reduce the impact of abandoned mines on our Nation's waterways.

Ambient $PM_{2.5}$ Research Program: In 1997, the U.S. Environmental Protection Agency (EPA) revised the standard for ambient (surrounding or circulating) air concentrations of $PM_{2.5}$. Ambient $PM_{2.5}$ comes from a variety of emission sources, both natural and caused by humans. Motor vehicle exhaust, power plants, forest fires, sea spray, and residential wood stoves all contribute. Burning coal to generate electricity produces primary $PM_{2.5}$ (e.g., fly ash and carbon soot) and the gaseous precursors (e.g., sulfur dioxide and oxides of nitrogen) to secondary $PM_{2.5}$ (e.g., ammonium sulfates and nitrates) that is formed in the atmosphere. FETC's $PM_{2.5}$ Research Program includes ambient air monitoring, characterizing primary $PM_{2.5}$ and investigating the formation and transport of secondary $PM_{2.5}$, and developing cost-effective control technologies for coal-fired power plants.

Mercury Emissions Control: FETC provided scientific data on toxic emissions from coal-fired power plants that formed the basis of two reports recently issued by the EPA: *Mercury Study* and *Study of Hazardous Air Pollutant Emissions From Electric Utility Steam Generating Units*. In response to concerns about mercury emissions from coal combustion, FETC is developing advanced mercury control technologies for coal-fired power plants. The current program focuses on augmenting existing pollutant control technologies (e.g., flue-gas desulfurization systems, electrostatic precipitators, baghouses) to cost-effectively control mercury emissions.

Carbon Dioxide Capture, Reuse, and Disposal: FETC is exploring carbon sequestration as a viable and economic method of addressing increasing levels of carbon dioxide (CO_2) in the atmosphere. Carbon sequestration is (1) the removal and storage of CO_2 for geologically significant time periods, either from the atmosphere or from the process streams of energy production and utilization systems; or (2) the use or reuse of the captured CO_2. Sequestration can be *direct*—capturing CO_2 at a power plant and then disposal or storage of the CO_2, or *indirect*—removing CO_2 from the atmosphere by enhancing natural sinks, such as planting more trees to absorb CO_2. Our carbon-sequestration efforts include methods that involve storing CO_2 in geologic structures such as unminable coal beds or oil, gas, and saline reservoirs; or in the oceans. Another way to reduce CO_2 levels in the atmosphere is to cofire coal with biomass, and FETC has initiated a bioprocessing program.

Clean Water—Protecting our Water Resources

Water: vital for life. We grew up expecting that we'd have an endless supply of clean, clear water—not only for drinking, but also to maintain our yards and gardens and to play in. In recent years, water quality and quantity problems have been undermining public confidence in water supplies, constraining industrial and community development, diminishing the value of recreational resources, and endangering traditional socioeconomic bases. Microbial contamination, acid mine drainage, industrial discharges, untreated sanitary wastes, agricultural runoff, other types of nonpoint source pollution, and flooding affect an ever increasing number of businesses, residents, visitors, and downstream neighbors.

FETC is working with partners in other agencies and the private sector to find improved ways to protect our water. FETC's Watershed Science and Technology Initiative supports a new cooperative approach to watershed protection where state, tribal, federal, and local governments, industry, and the public work together to identify problems and develop solutions. We use our technical capabilities to:

- ***Ensure*** effective regional and national integration of legal, regulatory, technical, and socioeconomic issues for consensus on common goals, actions, and timetables.
- ***Supplement*** diminishing federal and state resources for planning, modeling, monitoring, characterizing, protecting, and restoring water resources
- ***Develop*** and ***demonstrate*** more effective watershed characterization and treatment methods.

Recent projects include an evaluation of mine fire conditions and abatement alternatives along the boundaries of a lake in Kentucky, addressing the long-term effects of mine pool discharges in West Virginia, finding innovative solutions to acidic drainage problems encountered in building and maintaining roads and highways in Pennsylvania and West Virginia, and managing poultry litter, a major environmental issue in the Mid-Atlantic states. FETC helped design a county-wide watershed program for Preston County, West Virginia, that has become a model for other organizations seeking to solve environmental problems.

The Watershed Science and Technology Initiative cross-cuts programs and products. It's about finding real solutions to environmental problems now, regardless of the source. We use our expertise in engineering, systems analysis, project management, and partnering to help communities find the answers and funding to correct their watershed problems.

We hope the following articles pique your interest in FETC's environmental solutions. FETC is indeed finding a better way to protect the promise of the future—for our children and grandchildren.

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Private Sector Solutions

Say you had a pipe—a really L O N G pipe—that stretched from, say, Las Vegas, Nevada, to Pittsburgh, Pennsylvania. Say this pipe was, in all likelihood, radioactively contaminated. How would you figure out if it was indeed contaminated? And if so, to what extent, and exactly where?

These questions aren't as farfetched as it might seem. This is just about the scenario faced by the DOE Office of Environmental Management (EM) as it cleans up the facilities that were once part of the nuclear weapons complex.

For over 50 years, during World War II and the Cold War, the United States developed a vast network of industrial facilities for the research, production, and testing of nuclear weapons. This network, the nuclear weapons complex, includes thousands of large industrial structures: nuclear reactors, chemical processing buildings, metal machining plants, and the like. Now we are faced with cleaning up the contaminated soil, surface water, and groundwater, and the backlog of waste and dangerous materials at these sites. This cleanup cost—estimated at $147 billion—is often referred to as the "Cold War Mortgage" because it was deferred during the arms race to be paid in the future. Now the future has arrived.

To understand the scope of the problem, just look at the pipes. Some 53 former weapons production sites remain to be cleaned up. Just two of these sites, Hanford, Washington, and Fernald, Ohio, have about 10 million feet of 10-inch pipe that need to be surveyed for contamination. This is roughly the distance from Las Vegas, Nevada, to Pittsburgh, Pennsylvania—about 1,900 miles. At the three Gaseous Diffusion Plants (GDPs) in Kentucky, Ohio, and Tennessee, there is a combined total of 4.4 thousand tons of just one kind of pipe. That's the weight of 2,285 Ford trucks. That many trucks, parked bumper to bumper, front to end, would stretch almost 7½ miles.

The problem is huge, and clearly, innovative technologies to clean up and manage the DOE-generated wastes would be beneficial. This is where FETC's Industry and University Programs (IUP) comes in. IUP's mission is to foster private sector companies

to develop, demonstrate, and deploy cost-effective technologies that will be used to solve problems at multiples DOE sites. The underlying idea is that an open, competitive process will provide advanced technologies "faster, safer, and cheaper" than currently available environmental technologies. The program assists private sector companies, especially small businesses, in penetrating the DOE market with their technology solutions and services.

The Pipe Explorer™

One of IUP's successes is development and deployment of the remotely operated Pipe Explorer™ system to characterize radioactive contamination inside those hundreds of miles of pipes in the DOE complex. The baseline technology for conducting radiological surveys of pipes is passing a hand-held radiological sampling instrument over the exterior surface of the pipe. For a complete survey, personnel must gain access to the entire exterior surface over its full length. This is not always possible—often pipes are embedded in concrete, or are located beneath concrete slabs—and the process is difficult, time-consuming, potentially hazardous, and not highly sensitive.

The Pipe Explorer™ system—developed by Science & Engineering Associates, Inc. (SEA)—solves these problems by integrating a pipe locator, video camera, and alpha, beta, and gamma radiation detectors with a specialized membrane to survey radiologic contamination of pipes from within. The system's membrane is shaped something like a long, skinny balloon. Before the system is deployed, the tubular membrane is rolled up on a spool inside of an airtight canister with the open end of the membrane extending from an outlet on the canister.

To deploy the system, the end of the membrane is clamped back on the outside of the outlet, creating an air-tight seal. Pressurized air is then introduced into the canister. As the pressure builds, the membrane is reeled out of the canister, turning inside out as it goes. As the membrane inverts, it extends down the pipe, and lies along the sides of the pipe's interior. The detectors and camera are carried down the pipe inside the inverting membrane, which protects them from direct contact with any moisture or contaminants inside the pipe. The membrane is extended the length of the pipe, or up to its full length of 500 feet, with the detectors taking measurements as they are pulled along.

When the survey is complete, the detectors and membrane are retrieved by a tether attached to the far end of the membrane, next to the detectors. The membrane can be thought of as a balloon again, this time with a string (the tether) attached to the end on the inside. As the tether is reeled back up onto the spool, the membrane and detectors are pulled back out of the pipe, and the membrane re-inverts. Imagining the balloon, as the string is pulled out, the balloon ends up turning inside out. In this way, any contaminants picked up from the pipe end up on the inside of the membrane, minimizing risk to workers.

The Pipe Explorer™ system is not limited to straight pipes or pipes of one diameter; it is able to transport detectors around pipe elbows and through constrictions. Radiation detectors and video cameras have been deployed through pipes ranging from 2 to 18 inches in diameter, with multiple 90-degree elbows. Benefits of this technology include rapid, accurate radiological data over the entire pipe length (up to 500 feet); survey of locations inaccessible with existing technologies; and reduced personnel exposure, time, and costs.

Since October 1993, when development of the Pipe Explorer™ system began, two deployment systems have been developed that incorporate a video camera, pipe locators, and four different types of radiation detectors. These survey tools have been successfully used with the system at multiple DOE sites, and DOE has saved over $3 million by avoiding the cost of excavating and disposing of buried and encased pipes that could be left in place. The development of the Pipe Explorer™ system through FETC concluded in September 1997. SEA is now actively marketing the product to DOE deactivation and decommissioning (D&D) projects and commercial nuclear reactor D&D projects.

R&D Projects in the Industry and University Programs

Contamination in pipes is just one of the problems that needs to be addressed to clean up the former weapons complex. Through the Industry and University Programs (IUP), EM's Office of Science and Technology contracts with private sector companies and universities to conduct research and development (R&D) projects that solve cleanup problems identified by sites. Projects are selected competitively and are periodically evaluated for progress to justify continued funding and to ensure the projects are meeting site needs. Present and future projects encompass the entire range of environmental problems encountered at these sites:

- Mixed-waste characterization and treatment;
- Soils and groundwater remediation;
- Remediation of high level waste tanks;
- Decontamination and decommissioning of buildings and equipment;
- Contaminant characterization and monitoring;
- Worker health and safety requiring robotic operations or protective devices;
- Chemical and physical separation of contaminants;
- Emissions and long-term monitoring; and
- Pollution prevention.

Since 1992, when IUP was first implemented, FETC has entered into 99 R&D contracts with private sector companies, including many contracts with small businesses. Products resulting from these efforts are equipment, systems, processes, and services that will be deployed at DOE sites to help solve environmental problems. The program currently has 44 active contracts. Of the remaining projects, 27 have been completed and many of these are now being deployed at multiple DOE sites. The rest of the projects were terminated in early stages of development. The phased nature of the R&D contracts, with go/no go decisions between phases, allows for termination of technologies that do not "make the cut." Thus, terminated contracts do not represent "failures," but instead represent effective contract management; funding is continued only for those projects with the greatest potential for success.

Detecting Volatile Organic Compounds

Another example of a successful technology developed through IUP is the development of a portable unit to detect volatile organic compounds in the field. Field personnel are often hampered in their efforts to identify hazardous materials and monitor toxic waste site cleanups. Current methods are to set up mobile laboratories with skilled technicians and chemists at the site, or to obtain samples and transport them to a regional laboratory for identification and analysis. Either option is time-consuming and expensive.

Through a partnership with IUP, Electronic Sensor Technology (EST) has developed a portable, highly sensitive, rugged vapor detector system (the Model 4100 Trace Vapor Analyzer) that provides low-cost, accurate vapor detection and analysis. Based upon the application, the analyzer can be used in water, soil, vapor, and particle mediums. IUP supported development of the vapor analyzer to address problems detecting subsurface contaminants, a common problem at sites throughout the DOE complex.

The vapor analyzer has been used at the DOE's Savannah River Site in Georgia to detect the chlorinated hydrocarbons trichloroethylene (TCE) and tetrachloroethylene (also called perchloroethylene, or PCE). Both of these

compounds are common—TCE is used in spot removers, paint strippers, and industrial cleaners, while PCE is used by almost 90 percent of the nation's dry cleaners—and in small quantities, neither is harmful. But acute or prolonged exposure is a different story. In these cases, both compounds have been linked to adverse health effects, and in high doses, PCE is a probable carcinogen.

The vapor analyzer can sensitively detect both TCE (down to 10 parts per billion), and PCE (down to 3 parts per billion). It can also detect a wide range of other volatile organic compounds like gasoline, benzene, and diesel fuel. Not only is the analyzer highly sensitive, it's also quick; analysis times range from 5 seconds to 2 minutes. The vapor analyzer is now being marketed by EST for environmental applications, as well as for detection of narcotics, explosives, and nerve agents. Branches of the U.S. military have recently purchased the analyzer for detection of contraband.

This success story illustrates the philosophy of the Industry and University Programs (IUP). By partnering with a private-sector small business, from technology development through full-scale demonstration at DOE sites, IUP helped the company reduce its risk, and position itself to use their advanced equipment to address DOE's remediation needs and market its technology to non-DOE concerns.

Summary—Cost-Effective Cleanup

The success of IUP is measured, ultimately, by the bottom line. Will DOE see a return on the government's investment? Although cost projections could change as sites continue to define the market opportunities for cleanup technologies and services, current cost projections support a resounding ***yes***. IUP has received about $209 million in total funding to date. Projected cost savings for 15 technologies could be $800 million to $2.4 billion. At the lower estimate, this translates into a 4:1 return on the Government's investment; the upper estimate translates into a return of 11:1.

IUP is cost-effectively opening the DOE market for weapons complex cleanup to private sector companies. By keeping an eye on the bottom line, inviting competition, and leveling the playing field for all competitors, we all stand to gain. The Cold War Mortgage can be reduced, and we can return the environment to a healthier, more natural state.

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Current Status of IUP Contracts:

99 technology development projects funded to date, including 54 contracted to small businesses

55 completed contracts:

- 28 terminated in early stages of development
- 27 completed all phases; many deployed at multiple DOE sites

44 on-going projects:

- 21 ready for deployment within 1 year

Extent of the Problem

Some 353 projects exist at DOE's 53 remaining cleanup sites in the United States. The Environmental Management program intends to complete cleanup at most of the remaining sites by 2006. Current life-cycle estimates for cleanup total $147 billions through 2070.

Paul W. Hart
Product Manager, Deactivation and Decommissioning

Office of Product Management for Environmental Management

Tools for the Toolbox

Heavy equipment doesn't often elicit an emotional response. We pass by bulldozers, cranes, and backhoes, and we don't think much about them. The exception to this may be wrecking balls. There can be a sadness about them. Every building that's demolished takes with it a small piece of our history.

The exception to the exception may be when we tear down a piece of the nuclear weapons complex. This extensive complex of industrial facilities—thousands of structures all over the United States used for over 50 years to research, produce, and test nuclear weapons—represents a time in our history when we focused on weapons production and research, usually without regard to environmental consequences. When these facilities come down, we can feel more comfortable knowing that the arms race is over, and we have taken a large step back from the brink of nuclear Armageddon.

But, unfortunately, we can't go rushing in with a wrecking ball to raze these facilities right away. The legacy of the Cold War is that many of them are contaminated with radiological and chemical hazards. At many sites, there is a tremendous backlog of waste and nuclear materials. In addition to structures, the soil, surface water, and groundwater may also be contaminated, further complicating cleanup.

A problem this vast, this complicated, requires a wide range of solutions. FETC is providing some of these solutions through its Deactivation and Decommissioning (D&D) activities. D&D is one of five focus areas established by the DOE's Office of Environmental Management (EM)—the organization responsible for environmental restoration at virtually the entire weapons complex—through its Office of Science and Technology. These five focus areas—Tanks, Mixed Waste, Subsurface Contaminants, D&D, and Plutonium Stabilization and Disposition—represent EM's highest priority problem areas. These are the areas most in need of innovative technologies to solve the problems that hinder cleanup.

The D&D Focus Area (DDFA) is responsible for demonstrating and implementing advanced technologies that sites can use for deactivation and decommissioning—technologies that will increase worker safety and decrease cleanup costs. The cornerstone of DDFA activities is the Large-Scale Demonstration and Deployment Projects (LSDDPs). A suite of new technologies is demonstrated alongside competing baseline technologies at a DOE site being deactivated and decommissioned. Some of the technologies come from the private sector, others have been developed within DOE, but none have been deployed in the DOE complex. Each demonstration provides cost and performance data to help end-users determine whether or not they would benefit from a new technology. Successfully demonstrated technologies are available for immediate deployment on the remaining portion of the problem at the site, as well as on projects addressing similar problems elsewhere.

In 1995, a competitive Request for Letter Proposals was sent to all DOE Operations Offices requesting that they offer facilities to host an LSDDP. In January 1996, the first three facilities were chosen:

- **Chicago Pile 5 (CP-5) Reactor at Argonne National Laboratory - East,** a thermal reactor built to supply neutrons for research that operated for 25 years until deactivation in 1979.
- **Fernald Environmental Management Project (FEMP) Plant 1 Complex,** a seven-building complex that received all of the enriched uranium materials processed at Fernald, Ohio.
- **Hanford (WA) 105-C Full-Scale Plutonium Production Reactor,** a full-scale plutonium production reactor built in 1952 that operated until 1969.

Fifty-six new technologies were demonstrated at the three initial LSDDPs through their completion in fiscal year 1998. These included innovative technologies for facility characterization, decontamination, dismantlement, material disposition, and improved worker health and safety. Twenty-four of the technologies were eventually deployed in place of existing technologies. Since more than one site within the DOE complex may choose to use a given technology, the 24 technologies represent over 80 new deployments.

D&D Focus Area

When to Use The Wrecking Ball

So what are these technologies, and what are these projects? What is needed to decontaminate and dismantle a structure before a wrecking ball can be used?

Hanford is a 560-square-mile site located in southeastern Washington State, on the banks of the Columbia river. It was acquired by the federal government in 1943 to produce plutonium for national defense. Nine plutonium production reactors on the Hanford site now stand idle; the 105-C Reactor is one of these. The strategy for decontamination of these reactors is to place the reactor itself in a low-cost, safe storage condition for up to 75 years, pending its final disposal, and to decontaminate and demolish the surrounding structures. During the years that the reactors are in interim storage, radiological hazards, and the quantity of radioactive material will diminish substantially as a result of radioactive decay.

The project at the 105-C Reactor included demolition and removal of the 105-C building outside the reactor block shield wall, and removal of the fuel storage basin. The main problem in these areas was radioactive contamination on exposed surfaces. The challenge was to remove all of the contamination at the lowest possible cost. During the process, workers had to be protected; radioactive materials, including dust generated during surface removal, had to be contained; and the amount of material removed had to be minimized to reduce the costs and problems associated with disposal. During the course of the project, 20 new technologies were demonstrated at full-scale beside baseline technologies.

These included innovative technologies to

- Suppress dust from demolition activities;
- Sample potentially contaminated soils for laboratory analysis;
- Strip and remove concrete and coatings from walls and floors;
- Gauge workers' physical state while working in a heat stress environment;
- Provide safe temporary power in surplus buildings where electrical power was severed;
- Survey floors and walls for contamination; and
- Monitor personnel dose and area exposure rates remotely from a command center outside radioactively contaminated areas.

Thirteen of the demonstrated technologies were eventually deployed at Hanford. These technologies will benefit the 13 other full-scale production reactors within the DOE complex (five at the Savannah River Site in South Carolina, and eight more at Hanford). Commercial nuclear facilities, as well as other contaminated DOE facilities will also benefit.

Demonstration of Successful Technologies

Two of the more successful technologies demonstrated at Hanford were the Concrete Shaver, developed by Marcrist Industries Limited, and the Surface Contamination Monitor and Survey Information Management System (SCM/SIMS), developed by Shonka Research Associates, Inc.

The Concrete Shaver is a self-propelled, electric-powered shaving machine with diamond-impregnated blades for removing contaminated concrete and coatings. Contaminated concrete is a huge problem across the DOE complex; some 600 million square feet of concrete need decontamination, an area greater than 136 Sears Towers. The baseline technology against which the Concrete Shaver was compared is an air-powered scabbler. The Concrete Shaver removed concrete surfaces approximately five times faster than the baseline technology, it reduced costs approximately 50 percent, and less vibration for the operator reduced worker fatigue.

The SCM/SIMS is a motorized system for surveying floor and wall surfaces for radiation. The SCM/SIMS provides a visual representation of the surfaces surveyed, generates a data report detailing the actual numerical results, and overlays the data onto a CAD drawing. The baseline technology for this kind of survey and data analysis is a National Nuclear motorized floor-contamination monitor with an onboard computer and complemented by hand held detectors. The SCM/SIMS provided surveys three times faster than baseline for alpha contamination and seven times faster for beta/gamma contamination. The cost savings over baseline were approximately 30 percent, with an estimated savings of $183,000 per production reactor. If deployed at the 13 other production reactors in the DOE complex, this one technology alone would result in cost savings of over $2.3 million. The SCM/SIMS has already been deployed at several DOE and non-DOE sites, and in some cases has detected contamination in areas previously though to be "clean."

Four New LSDDPs

In March 1998, four new facilities were selected to host LSDDPs. One of these will focus on transuranic waste and will be hosted by Los Alamos National Laboratory (LANL) in Los Alamos, New Mexico. Transuranic waste is waste that, per gram, contains greater than 100 nanocuries of alpha-emitting transuranic elements—elements with atomic numbers greater than uranium, which includes plutonium—with half-lives greater than 20 years. These wastes are of special concern because of their long half-lives (the time it takes for half of the radioactivity to disappear). LANL currently has 2,400 cubic meters of oversized metallic transuranic waste—including 313 plutonium-contaminated gloveboxes—in retrievable storage. Ten to 12 improved technologies will be demonstrated at this project to improve management of transuranic waste. The technologies demonstrated should benefit the deactivation and decommissioning of over 1,800 contaminated gloveboxes throughout the DOE complex.

The second new project will be the Mound Tritium LSDDP in Miamisburg, Ohio. The Mound Plant is a 350-acre site about 10 miles from Dayton, Ohio. The goal of the environmental activities at Mound is to make the property, equipment, and facilities available for eventual development as a commercial industrial site. The Project will involve four main facilities with over 400 tritium laboratories and over 275,000 square feet of floor space—an area one and a half times the size of the U.S. Capitol. The laboratories contain fume hoods, miles of piping, 1,000 linear feet of gloveboxes, and other equipment contaminated with tritium, a radioactive form of hydrogen used in the fusion stage of nuclear weapons. Twenty to 25 improved technologies are expected to be demonstrated that will benefit other tritium-contaminated facilities at Mound and at the Savannah River Site.

The third new LSDDP will be at a 60,000-square-foot facility on the Savannah River Site contaminated with small quantities of highly enriched uranium. Uranium in its natural state contains atoms in two forms: 99.3 percent of them are in a form called uranium-238, or U-238, and 0.7 percent are in a form called U-235. When uranium has been processed to contain more than the natural amount of U-235 (0.7 percent), it is called enriched; when the amount exceeds 20 percent, it is said to be highly

Help From the Corps

As part of an interagency agreement with the Deactivation and Decommissioning Focus Area, the U.S. Army Corps of Engineers (USACE) provides validation of cost and performance results for Large-Scale Demonstration and Deployment Projects (LSDDPs). The USACE conducts life-cycle cost analyses for the technologies that are demonstrated in the LSDDPs. These analyses can by used by end-users in their decisions about deploying new technologies.

enriched. Highly enriched uranium remains in the ventilation ducts, processing systems, and other areas of the building that will be deactivated in this project. The project will demonstrate eight to ten advanced technologies that will improve safety, reduce costs, and accelerate the schedule for deactivation.

The Idaho National Engineering and Environmental Laboratory (INEEL) will host the fourth new LSDDP. This site in southeastern Idaho holds 52 reactors of various types, most of which have been deactivated or decommissioned to some degree. During this project, technologies for underwater inspection, characterization, decontamination, and dismantlement will be demonstrated at two water-cooled and -moderated research reactors (called "bathtub reactors") and a 30,000-gallon interconnecting water canal. (That's about the size of a backyard swimming pool.) These small reactors, built to develop and test nuclear components, are contaminated with lead, chromium, and radioactive elements. Improved technologies for underground work will be demonstrated on two underground facilities on the site with confined entries. The difficult access, coupled with the potential for contamination by asbestos, mercury, lead, and radiation, will require the use of robotic technologies so that work can be done remotely. The project will demonstrate at least 16 technologies that will benefit numerous reactor facilities and fuel storage pools throughout DOE and the commercial sector.

Deactivation and Decommissioning—A Summary

Although the LSDDP is at the core of DDFA activities, the work doesn't stop there. The DDFA is helping to assess the costs and risks of disposal alternatives for a building previously used for chemical processing at the Hanford site. The assessment will help lower costs for final disposition of similar buildings throughout the DOE complex. The DDFA is also promoting the use of previously demonstrated technologies at other sites through Accelerated Site Technology Deployment projects in Colorado, New Mexico, Idaho, and Ohio.

"The ultimate goal of the Deactivation and Decommissioning Focus Area is the rapid deployment of better technologies to reduce DOE's surplus facility mortgage."

Paul Hart
D&D Product Manager

All of these activities have a common goal: to put more technologies "in the toolbox" for use at D&D sites. Sometimes a wrecking ball is what is needed to bring a building down. Sometimes what's needed is something more specialized. Having the right tool at the right time in the right place will lower costs, reduce the risk to workers, and benefit us all.

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What is a Nanocurie?

A nanocurie is one billionth (10^{-9}) of a curie. A curie—named after Marie Curie, co-discoverer of radium in 1898, and winner of the Nobel prize for physics in 1903 and for chemistry in 1911—is a basic unit used to describe the radioactivity of a material. A typical home smoke detector contains about 1 millionth (10^{-6}) of a curie of radioactivity.

The Glovebox

The glovebox is one of the more appropriately named pieces of laboratory equipment. It literally is a box, with gloves that extend into it. The box is sealed, either to protect the technician from the contents of the box, to protect the contents from external contamination, or to maintain a unique environment within the box—an oxygen-free environment, for example. The contents of the box can be viewed through a viewport, and the technician can handle the box contents through the gloves that extend into the box.

The Alpha, Beta, Gamma of Radiation

Radiation is the process by which energy is emitted as particles or waves. The energy that is emitted is also called radiation, or radioactivity. Radiation is a natural part of our lives. In fact, some forms of radiation are necessary for life on earth. More than 80 percent of the radiation we receive comes from natural sources like sunlight, soil, and certain kinds of rocks.

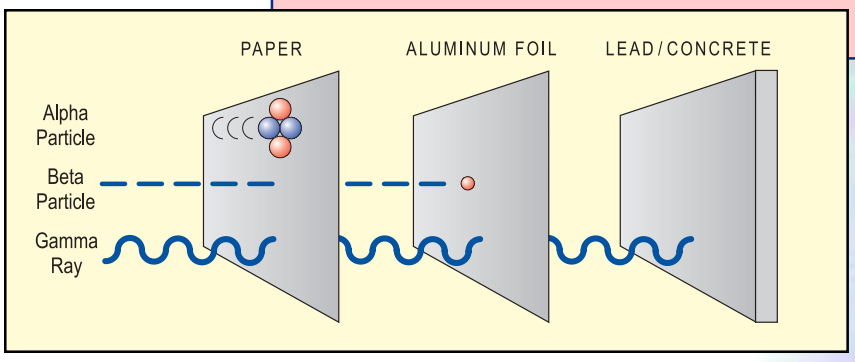
Both radiation and heat are produced when the nucleus of an atom splits. Nuclear power generation uses the heat from this kind of reaction to turn water into steam to produce electricity. When the nucleus splits—either naturally or as part of a laboratory process—the radiation released is in the form of alpha particles, beta particles, or gamma rays.

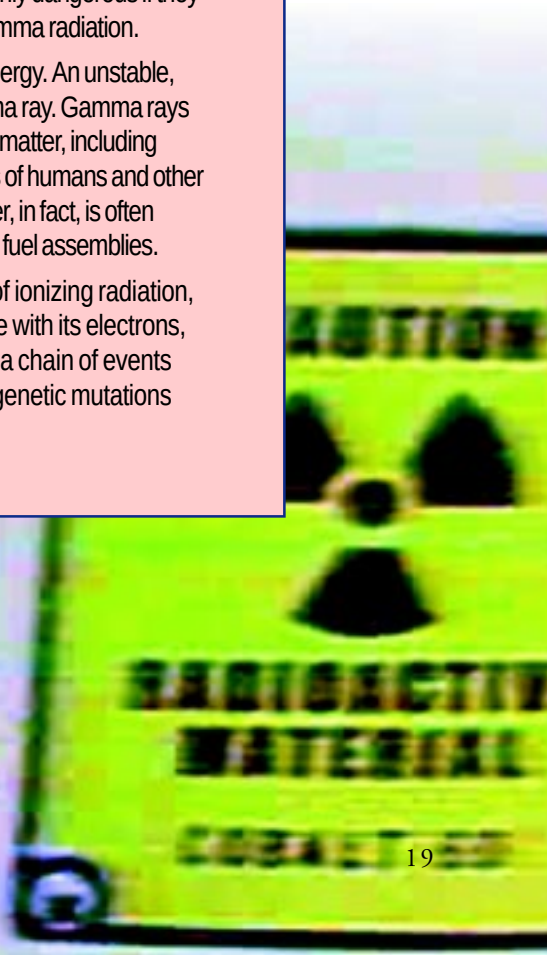
An alpha particle is made up of two protons and two neutrons bound together, the equivalent of a helium nucleus. Some elements naturally undergo alpha decay, the spontaneous emission of alpha particles. Alpha particles are emitted at very high velocity—about 10,000 miles per second—but because of their size they can only travel a few inches in the air. Alpha particles are easily shielded by a sheet of paper or a person's skin, but if they are eaten or inhaled, they can cause considerable damage. Per unit of energy, they are much more harmful than either beta or gamma radiation.

There is more than one kind of beta decay. In these reactions, either a neutron turns into a proton (and a negative beta particle is emitted) or a proton turns into a neutron (and a positive beta particle is emitted). Tritium is an example of an element that undergoes beta decay. Tritium is a form of hydrogen with two extra neutrons in the atom's nucleus. Beta decay in tritium occurs when one of the neutrons turns into three particles: a proton, an electron, and an antineutrino. The proton stays in the nucleus, and the electron and antineutrino are thrown off. The ejected electron is called a beta particle. Beta particles are more energetic than alpha particles, but they still can only travel in air for a few feet. They can pass through a sheet of paper, but they are stopped by aluminum foil or glass. Like alpha particles, beta particles are only dangerous if they are eaten or inhaled. Beta particles are often accompanied by gamma radiation.

Gamma rays, unlike alpha or beta particles, are waves of pure energy. An unstable, highly energetic nucleus will eliminate its extra energy as a gamma ray. Gamma rays are essentially high-energy x-rays. Like x-rays, they will penetrate matter, including skin, and because of this they can have severe effects on the cells of humans and other animals. They are stopped by lead, steel, concrete, or water. Water, in fact, is often used at nuclear power stations to isolate radioactive spent nuclear fuel assemblies.

Alpha particles, beta particles, and gamma rays are all forms of ionizing radiation, meaning that when they interact with an atom they can interfere with its electrons, leaving behind a charged atom, called an ion. This can initiate a chain of events that can result in problems to living things, up to and including genetic mutations (leading to cancer) and cell death.





Charles E. Schmidt
Product Manager, Environmental
Office of Power Systems Product Management

Using Fossil Fuels While Managing CO_2

The global climate-change debate continues—and the focus is reducing projected growth in CO_2 concentrations in the atmosphere. About 80 percent of the world's anthropogenic or human-caused CO_2 emissions are associated with energy use, and fossil fuels supply about 75 percent of that energy (85 percent in the U.S.).

Sequestration may be the answer! FETC is exploring several options that hold technical, economic, and environmental promise for mitigating levels of CO_2 in the atmosphere. These options underpin the center's carbon-sequestration effort, which Chuck Schmidt notes, ". . .is a form of carbon management that allows the continued use of fossil fuels while addressing climate change issues."

Sequestration is broadly defined as the *removal and disposal*, for geologically significant time periods, of CO_2 either from the process streams of energy systems or from the atmosphere, or *use or reuse* of the captured CO_2. Sequestration can be direct or indirect.

FETC is leading research on geological sequestration. Because fossil fuels are widely used by so many U.S. utilities—and many are located in areas removed from major bodies of water—storing CO_2 in the Earth is the most likely sequestration option. Better coal and gas technologies—which FETC develops in conjunction with private companies—will, in time, lower the cost of advanced coal-fueled power systems. These systems will most likely be able to produce concentrated streams of CO_2, making it easier for sequestration to be an integral part of advanced energy production.

While carbon management holds some seemingly attractive options that can ultimately reduce greenhouse gas emissions, three challenges remain: how to lower overall costs, how to choose a broad suite of sequestration methods, and how to ensure that sequestration does not introduce new environmental

Direct sequestration is capturing CO_2 at the source, such as a power plant, and then storage or disposal of the CO_2. For example, direct sequestration is being used in the production of natural gas from the North Sea. CO_2 that is removed from the produced gas as part of cleanup operations is pumped into a saline reservoir some 800 meters below the ocean floor.

Indirect sequestration is removing CO_2 from the atmosphere by enhancing natural sinks, such as (1) planting trees and accelerating vegetation growth, or (2) adding nutrients to an ocean's surface waters to increase the population of phytoplankton, the basic building block of the oceanic food chain. In the latter example, CO_2 removed from the surface waters is then replaced by that drawn from the atmosphere.

problems. For example, no one knows for sure how long CO_2 stored in rock formations that once held natural gas can remain, or whether CO_2 can move to other geologic formations and eventually seep to the surface.

Determining Long-Term Stability

Even if CO_2 stored in rock formations does make its way to the surface, little harm would be expected. However, the CO_2 would become part of the atmospheric loading in a much shorter time frame than desired. Industry practice appears to support geologic sequestration. In a 1998 paper on carbon management, Harvard University professors of science and chemistry E.A. Parson and D.W. Keith noted, "Injection of supercritical CO_2 into oil and gas reservoirs, and its long-range pipeline transport, have been long practiced for enhanced oil recovery (EOR). Adding separated CO_2 to depleted reservoirs and current injection sites would accomplish sequestration with little change to current practice."

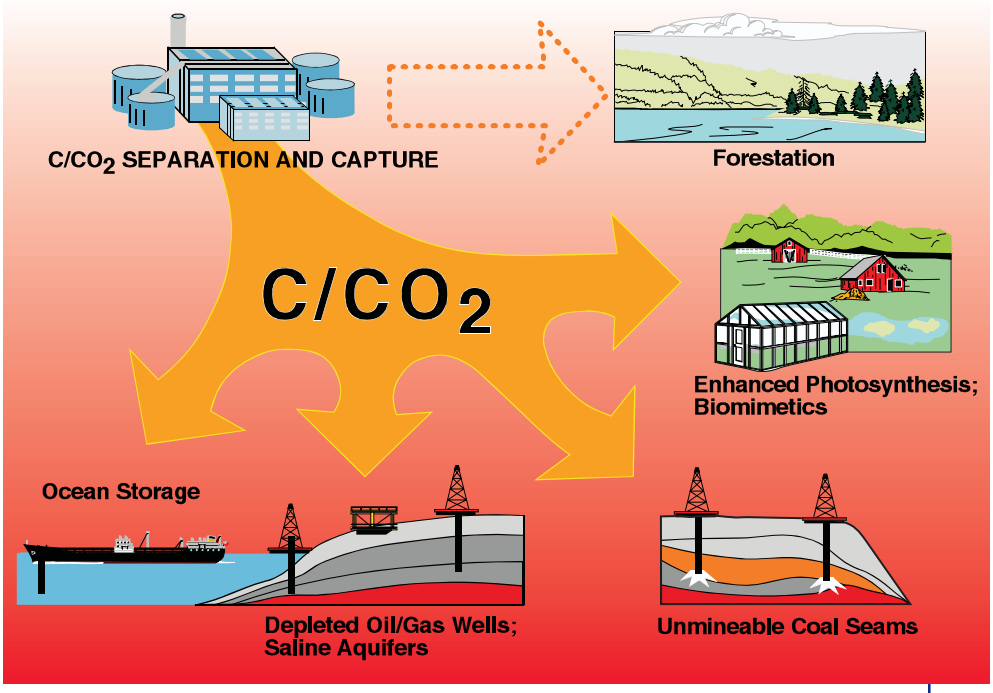
Still, they caution that more research is needed to determine the stability of long-term geologic sequestration. In fact, all methods of sequestration require more research, and that's where FETC takes an active role. We are adopting a multifaceted approach to developing a robust portfolio of carbon-sequestration technologies. Key elements include developing revolutionary concepts to drastically lower the costs of removing and concentrating CO_2 from fossil-fuel process streams, and identifying and verifying appropriate storage sites. The primary storage sites to be researched are geologic structures like oil and gas reservoirs, saline reservoirs, and deep coal seams. We are also considering indirect sequestration techniques, such as ocean and terrestrial systems and how to integrate fossil fuel production and utilization into enhancing these natural CO_2 sinks.

The ultimate goal of the sequestration program is to develop appropriate sequestration technologies to offset all growth projected for carbon emissions (business as usual) after the year 2010, with reductions beginning in 2015. This would result in hundreds of million of tons of carbon sequestered by 2020.

Sequestration Options

Unminable Coal Beds: As much as 90 percent of the U.S. coal resources, estimated at nearly 6 trillion tons, cannot be mined economically because coal seams are too thin, too deep, or the quality of coal is too poor. These spacious, unminable seams may be a near-term solution for storing CO_2 because, as laboratory demonstrations indicate, CO_2 is absorbed readily by coal and strongly adheres to coal surfaces. In addition, when CO_2 is used to displace methane in coal-bed methane-recovery operations, nearly three parts of CO_2 are needed to produce one part of methane—and the CO_2 remains in the coal.

FETC is participating in a methane-extraction effort in Alberta, Canada, that is supported by the Alberta Research Council and an industry-government consortium. FETC joined this effort through the auspices of the International Energy Agency's Greenhouse Gas Programme (IEA GHG), of which the U.S. is a member. This "piggyback" strategy enables FETC to participate in a $4 million project (FETC's contribution is $30,000) that could demonstrate sequestering CO_2 in coal seams while possibly using the produced methane, which can be sold commercially, to offset the price of CO_2 injection. If the produced methane were cofired with coal in a



utility boiler, incorporating methane production with CO_2 sequestration would also lower the emissions of other pollutants associated with coal combustion, such as SO_2, NO_X, and particulates.

Ocean Sequestration: The oceans of Earth are well-suited for storing CO_2, primarily because oceans naturally contain at least 50 times more CO_2 than the atmosphere. Also, oceans offer the largest storage capacity for CO_2—some estimates list the potential capacity as greater than 10,000 gigatons. Yet, researchers are quite mindful that our very existence is tied to the natural cycles of the oceans, and have placed determining potential environmental effects as the number one research objective.

An international project led by Japan is focusing on the technical feasibility and environmental impacts of ocean sequestration. FETC is part of this $4 million cost-shared project, which is located off the coast of Hawaii where deep ocean research has been ongoing for about 30 years. The project will involve injecting liquid CO_2 into the ocean at about 500 meters below the surface.

Saline Reservoirs: Deep saline reservoirs, large pockets of salt water imbedded far below the Earth's surface, are also considered to be a good, long-term underground option for CO_2 storage. They are large—it is estimated that they can hold more than 500 gigatons of CO_2, and have been used routinely by the oil industry for reinjection of brine as part of EOR. Saline reservoirs are considered a good option for sequestration because they are located throughout the U.S. and near most of our power plants.

Cofiring Coal With Biomass: Because biomass—agricultural waste such as wood chips—is a renewable, low-emissions fuel, it is being pursued as a way of reducing CO_2 output while using coal. Burning biomass to produce energy is nearly CO_2-neutral, meaning that the CO_2 released during combustion is consumed in growing the biomass. Biomass is high in moisture and low in density. Thus, it is more economic to burn biomass with coal in a large boiler that generally offers efficiency advantages compared to smaller units that burn biomass alone. Because cofiring would take place in existing coal-fired utilities, this greenhouse-reduction option is viewed as a near-term approach if technologic and economic uncertainties can be resolved.

Steps in that direction are being taken as FETC partners with EPRI and utilities in demonstrating coal-biomass cofiring. The most recent cofiring project is at the General Public Utilities Seward Plant. Sawdust and coal are to be cofired in a 32-megawatt (MW) wall-fired boiler using a separate biomass-injection system. A similar effort at Northern Indiana Public Service Company's Bailly Station, also slated for the end of 1998, uses blends of urban wood waste, petroleum coke, and coal in a 160-MW cyclone boiler that includes an advanced scrubber, which was successfully demonstrated in the Pure Air on the Lake Project through the Clean Coal Technology Program.

Vision 21: Whatever the outcome of those projects, it is clear that future technologies and power plants will be affected by greenhouse-gas emissions control. A case in point is Vision 21, a DOE and FETC initiative that seeks to build ultra-clean, ultra-efficient fossil-fueled power plants capable of producing an array of energy products—not just electricity alone—by 2015. The Vision 21 program plans to integrate emerging concepts for high-efficiency power production and pollution control, leading to a new generation of fuel-flexible energy plants.

A fleet of Vision 21 energy plants will generate electricity and steam, premium chemicals, and clean liquid fuels more efficiently and cleanly than today. Because efficiencies with coal as the feedstock are to reach 60 percent and 75 percent if gas is used, the Vision 21 plants will require less fuel, which will result in fewer emissions overall—including CO_2. In addition, Vision 21 plants can be equipped with a

CO_2-capture device, making the Vision 21 plants "zero-discharge" plants.

In terms of pollution control, these plants can capture pollutants and either dispose of them or convert them into marketable co-products. The plants will reduce CO_2 and other greenhouse gases; then carbon emissions can be separated and captured at the plant or offset by carbon removal processes applied elsewhere. The captured carbon can be sequestered or perhaps recycled into useful products.

Reducing Emissions and Wrestling With Economics

Some utilities in the U.S., pinpointed as large CO_2 emitters, have taken tentative steps toward greenhouse gas mitigation by enhancing natural sinks. These steps include managing biomass operations that will provide fuel for biomass-coal cofiring, and sponsoring the planting of trees in rainforests.

Industrial sources are also large emitters of CO_2. Natural gas fields, for example, can contain as much as 20 percent pure CO_2, which must be removed before pipeline quality gas is produced. This makes natural gas operations a logical starting point for implementing and testing CO_2-capture techniques. FETC is conducting research initiatives that aim at reducing the cost of CO_2 capture.

The world's first-known commercial, point-source, CO_2-sequestration project began in the fall of 1996 in Norway when Statoil began storing CO_2 from one of its gas fields in a sandstone aquifer 800 meters below the ocean floor, or about 1,000 meters below the North Sea. A floating rig uses five pipes to channel and store 20,000 tonnes a week of CO_2, roughly the same amount of CO_2 produced at a 140-MW coal plant. The incentive for sequestration is the Norwegian carbon tax at $50 a tonne (of CO_2); sequestration costs amount to $15 a tonne of CO_2 removed. An international effort aimed at documenting the CO_2-capture method from natural gas fields is being formed with the idea of replicating it in the near future.

Costs always factor into technological development and carbon sequestration is no different. For industry, and especially utilities, to adopt a long-term CO_2-mitigation strategy, capital requirements have to be reasonable and returns on the investment have to be tempting.

We have estimated that the costs of capturing CO_2 at the point source, transporting it to the coast, and sequestering it deep within the ocean's depths are in the $50- to $75-per-ton range. Such costs would nearly double the retail cost of electricity, an expense most Americans would not be willing to pay. In addition, more than 30 percent of power now generated would be "parasitically consumed" by the capture-and-disposal process.

DOE's Office of Fossil Energy's goal is to reduce sequestration costs to $10 per ton. The challenge is clear: sequestration costs must be substantially reduced. FETC has developed and is orchestrating research initiatives to do just that.

FETC

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How Much CO_2?

The United States emits more than 5 gigatons (billion tons) per year of the world's CO_2 into the atmosphere. This is equivalent to a gigantic block of dry ice that is 1 mile square by about 3/4 mile high.

Thomas D. Brown
Project Manager, Advanced Crosscutting Technologies Division

Office of Project Management

Quicksilver
Don't Play With It!

The Mad Hatter was aptly named. Lewis Carroll fortuitously used science when he named the character in his 19th century novel, *Alice in Wonderland*. Erratic behavior was a symptom of a nervous disorder of the time related to the use of mercury during the hat-making process.

The English language implies the dangers of mercury—a person with a mercurial temperament is erratic, changeable, fickle—and history documents its hazards. From the late 1800s to the 1950s, nervous disorders were linked to mercury miners in Spain's Almaden mines. Between 1953 and 1960, a chemical plant dumped mercury-containing sludge into Japan's Minamata Bay, resulting in the death of up to 700 residents of the nearby village, as well as fish, birds, and other animals. The incident produced some of the first evidence of toxicity from eating mercury-contaminated foods. When Iraqi residents were poisoned by eating grain seeds contaminated by methylmercury, the U.S. Environmental Protection Agency (EPA) used the tragedy to establish a

mercury limit for fish. In 1976, the World Health Organization indicated that human exposure to methylmercury compounds comes almost exclusively from the consumption of fish and fish products.

Incidents such as these have left government, industry, and consumer groups clamoring for information about mercury. While health studies related to mercury have been done in the past, research to measure mercury in flue gas from fossil fuel combustion—as well as hazardous, medical, and municipal waste combustion—has only been extensively conducted during the past 10 years. Furthermore, most of the relevant studies have occurred only within the last six years and have primarily focused on coal-fired electric utilities.

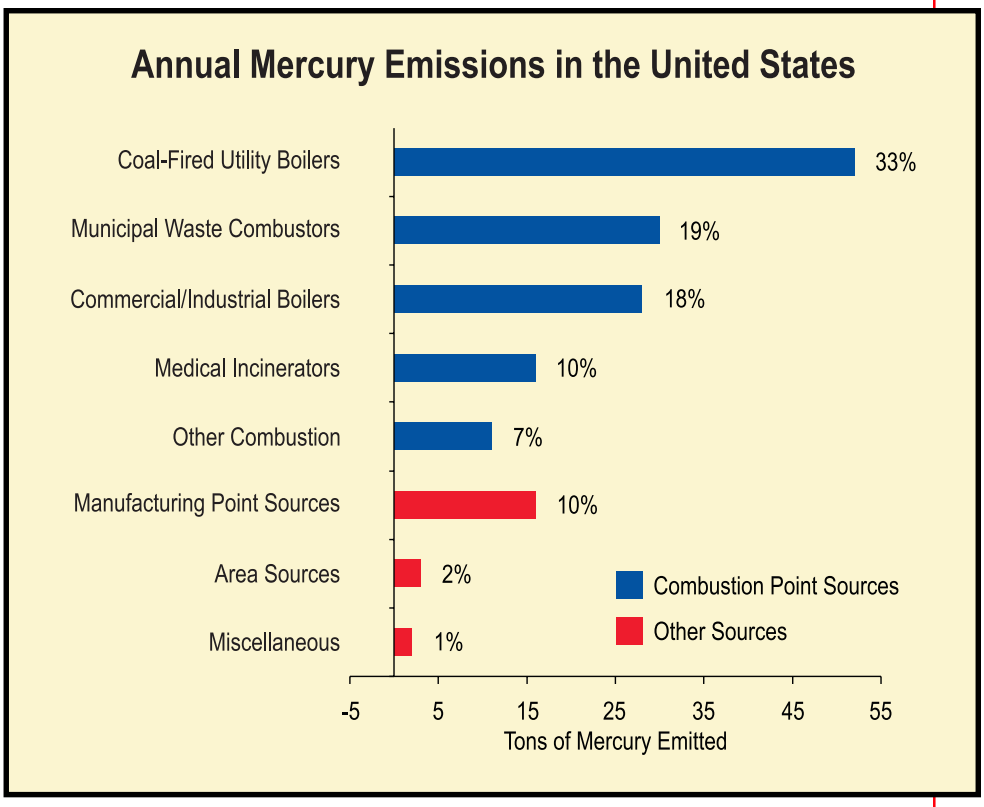
FETC has taken a lead role in addressing nationwide mercury issues, including revisions of two major EPA reports: *Mercury Study* and the *Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generating Units*. These reports indicate what the EPA calls a "plausible link" between mercury emissions from coal-fired utilities and the bioaccumulation of mercury in the food chain.

Our mercury program is the largest such program within the federal government. Our focus is the characterization of mercury and control of mercury in utility flue gas streams. We have addressed nearly every national and international mercury issue, including mercury transport and deposition from the atmosphere, methylation, bioaccumulation in the food chain, health effects, and collecting mercury information for federal agencies involved in making policy and regulatory decisions.

Mercury and its Health Impact

If you are old enough, you may remember playing with mercury, descriptively nicknamed quicksilver, in a science class. Scientists now know that mercury, a naturally occurring element, presents a health hazard because it's a neurotoxin, meaning that it's poisonous to the nervous system.

According to EPA's *Mercury Study*, mercury in the environment comes from both natural and human, or anthropogenic, activities. Most of the mercury in the atmosphere is elemental mercury vapor, which can circulate in the atmosphere for up to a year and therefore can be dispersed and transported over a wide area. Most of the mercury in water, soil, sediments, plants, and animals exists in the form of inorganic mercury salts and organic forms of mercury, such as methylmercury. Inorganic mercury, when airborne or in a gaseous form, comes back to Earth during precipitation but can also be dry-deposited. Wet deposition is the most common way for mercury to travel to surface waters and land. Mercury accumulates efficiently in the aquatic food chain, and predatory organisms tend to have higher mercury concentrations. And nearly all of the mercury accumulating in fish tissue is methylmercury.



Combustion point sources account for 87 percent of the annual mercury emissions in the U.S., or 137 of the 158 tons emitted per year. Manufacturing point sources include chlor-alkali, cement, and pulp plants. Area sources include dentistry, paints, and labs.

The deposition of mercury in waterways raises concerns for people who consume fish as part of a basic, nutritious diet in their daily lives. According to the EPA, mercury levels in our food and water supplies generally are below levels of concern. But the concern remains because fish consumption is a prime pathway for human and wildlife exposure to methylmercury. The exposure and risk, however, are dependent on the kind of fish, the concentrations of methylmercury, the quantity of fish consumed, and how often one eats fish.

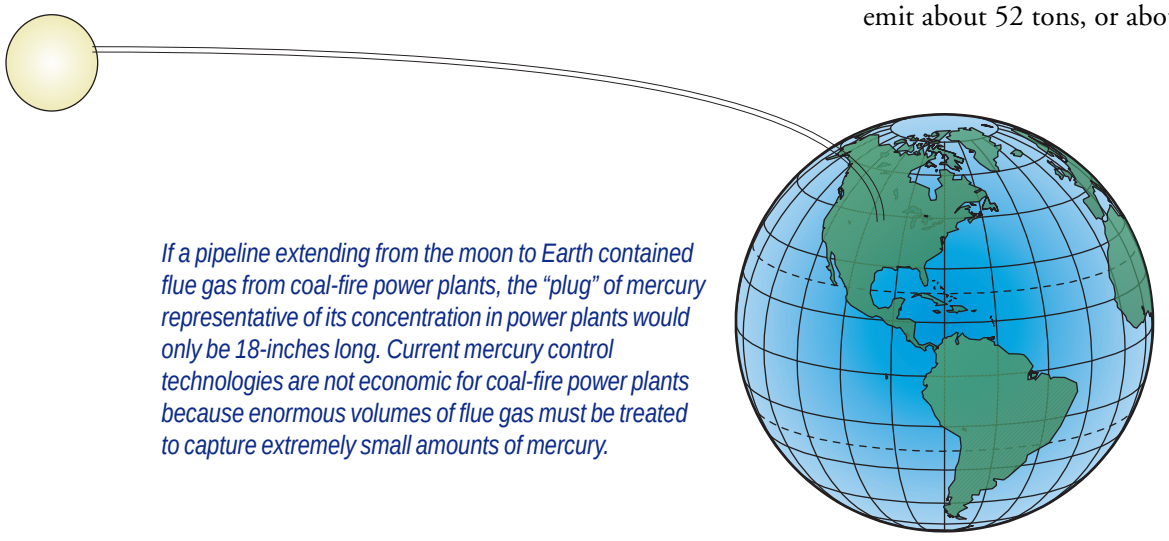
Of particular concern is the population of women of childbearing age because the fetus may be very sensitive to the effects of methylmercury. Two ongoing studies supported by U.S. and European federal governments seek to relate a maternal mercury dose from eating fish and other seafood containing methylmercury to neurological problems associated with child development. The studies, one conducted in the Indian Ocean island called the Republic of Sychelles and the other being conducted in the Faroe Islands located in the Northern Atlantic Ocean, are similar in design but present data that are controversial in nature and contradictory. The health effects of low chronic exposure to mercury have not been established from these studies and further evaluation is needed.

Since these two current studies and others on mercury emission impacts are producing new and somewhat controversial and contradictory data, the federal government will take another look at what constitutes safe levels of exposure by determining the lower threshold limit of methylmercury in fish and other seafood. At the direction of Congress, the EPA is having the National Academe of Sciences (NAS) conduct an 18-month study to evaluate all the health related mercury data that have been collected and to provide information to determine the lower threshold limit of methylmercury in fish and other seafood for safe consumption.

In the U.S., 39 states and some Native American tribes have issued advisories that restrict the consumption of fish from certain freshwater sources. The NAS study could indicate a higher mercury threshold in fish and many of the advisories could be eliminated in future years. The EPA states now that a child in a lower elementary grade could be at risk as a result of eating a 3 1/2 ounce can of tuna regularly in his or her lunch.

Mercury and Electricity Production

Mercury is a naturally occurring substance, but human activities contribute to the amount of the element we find in our air and water. According to recent emissions studies, most of the mercury emitted into the air comes from electric utilities, municipal waste combustors, commercial and industrial boilers, medical waste incinerators, and chlor-alkali plants. Of those sources, coal-fired utilities are estimated to emit the most mercury: U.S. coal-fired utilities emit about 52 tons, or about 1



If a pipeline extending from the moon to Earth contained flue gas from coal-fire power plants, the "plug" of mercury representative of its concentration in power plants would only be 18-inches long. Current mercury control technologies are not economic for coal-fire power plants because enormous volumes of flue gas must be treated to capture extremely small amounts of mercury.

percent of the 5,000 tons emitted worldwide per year. The most common characteristics of the coal-fired power plant thought to influence mercury emissions are the coal rank, mercury and chlorine content of the coal, components of the fly ash, and the design and operation of the pollution control devices.

Pollution control devices already reduce—by 30 percent—the estimated 73 tons of mercury *entering* all utilities. But no specific control technology is in place for *removing* the 52 tons of mercury that are emitted each year, 17 tons of which redeposit within the U.S. Mercury control technologies are installed on municipal waste combustors, medical waste incinerators, and chlor-alkali plants, but they are not applicable for the coal-fired electric utility industry—because of the large volume of flue gas that must be treated to capture extremely small amounts of mercury.

The *Mercury Study* report notes that, ". . .most control technologies for coal-fired boilers are in the research stages, making it difficult to predict final cost effectiveness and time needed to commercialize the technologies." The development of low-cost control technologies for mercury will provide critical data and information to policy and regulatory agencies to make sound and rational decisions on mercury emissions control. In addition to evaluating ongoing health studies, EPA—with major support from FETC and EPRI—is ready to establish mercury control strategies. The result may well be that EPA will decide to regulate mercury emissions from power plants. Such regulations would potentially control the amounts of mercury emitted and would guide utilities toward wise decisions regarding technology choices.

The goal is to eventually ensure bodies of water that are nearly free of anthropogenic mercury with healthy fish, thereby reducing the risks to those animals who eat fish or thrive on the food supplies contained in the water. While the fish population has drawn more attention, studies indicate that other wildlife—the Florida panther, loons, eagles, minks, and otters—have varying levels of mercury contamination. Current transport and deposition studies must be continued to determine if mercury emissions from coal-fired utilities do contribute to the bioaccumulation of mercury up our food chain. This will have a major impact on any regulatory determination.

FETC's Mercury-Control Projects—Phase II

- ADA Technologies, CONSOL Inc., Public Service Gas & Electric, and Burns and McDonnell—Further develop a process that efficiently removes all forms of mercury. This system includes sorbent regeneration and mercury recovery. The project is valued at $1.1 million over 24 months.
- Physical Sciences, Inc. (PSI)—Conduct a $3.4-million, 36-month project to establish ways to predict the distribution and fate of mercury, arsenic, chromium, and their chemical forms during various combustion conditions, which in turn will provide strategies for their removal.
- Radian International LLC, EPRI, and Meserole Consulting—Address the conversion of elemental mercury to a more soluble form so that more than 95 percent of it will be removed in wet flue gas desulfurization systems. The project is valued at $895,000 over 36 months.
- Public Service Company of Colorado, ADA Technologies, and EPRI—Participate in a $1.5-million, 36-month project to demonstrate mercury removal through a pilot-scale technology that injects carbon, or other solid chemical-capturing material, as part of an air pollution control device such as an electrostatic precipitator or fabric filter.
- ABB Power Plant Laboratories, Combustion Engineering, Inc., and ADA Technologies—Conduct a $1.3 million, 30-month project to investigate novel ways to improve electrostatic precipitators to more efficiently collect small particles and trace toxic metals associated with these particles.
- University of North Dakota, Energy and Environmental Research Center—Conduct an $840,000, 24-month project to study an advanced hybrid particulate collector that has a greater than 99.99 percent collection efficiency rate for all particle sizes, can be used with all U.S. coals, and is cost-competitive with existing technologies.

FETC, EPA, and EPRI; state agencies from Michigan, Minnesota, and Wisconsin; and Canada have initiated a proposed plan to study the fate of mercury in the Lake Superior Basin. The plan is to accurately predict the relationship between source mercury emissions (four utilities firing coal—two in the United States and two in Canada), and bioaccumulation of mercury in fish in Lake Superior and nearby water. A team of leading experts in mercury measurement, transport, deposition, methylation rate, and bioaccumulation has been assembled to plan and conduct the research.

Mercury Control Strategies

FETC characterizes and develops technologies to address hazardous air pollutants, known as air toxics. We recently focused on a two-phase program aimed directly at characterizing and controlling mercury emissions. Beginning in 1995, Phase I included 11 two-year mercury control projects. The projects included laboratory and bench-scale testing and evaluation of a number of approaches to control emissions. In general, the research had a three-pronged approach: add sorbents to adsorb the mercury, such as activated carbon—highly porous carbonaceous material with exceptional adsorptive properties; improve the mercury capture of existing pollution control technology; and develop new technology.

The underlying premise for Phase I was that no technology can be commercially used by utilities until researchers fully understand the mechanisms behind flue gas and mercury chemistries during combustion and post-combustion conditions. They also had to understand the complexities of interaction between fly ash and vapor-phase constituents.

Recently, FETC selected six proposals in Phase II to further investigate and develop mercury control technologies and concepts. This two- to three-year effort will be cost-shared by EPRI and the contractors. Since the maturity level of these technologies is relatively low, commercial deployment is expected to be at least several years away.

EPA's Information Collection Request

In response to a 1990 Clean Air Act Amendments requirement for more sampling and measurement of mercury in coal, EPA's Information Collection Request (ICR) calls for all utility power plants to report mercury concentrations on a weekly basis for a year. EPA is also requesting that approximately 75 specific power plants submit data on the concentration of mercury species in flue gas during one sampling event.

FETC has been asked by EPA to assist in developing the Quality Assurance and Quality Control of the ICR, which is critical in obtaining meaningful data to be used for determining the mercury inventory of the coal-fired utility industry. In addition, FETC has been asked to guide the statistical analyses for determining the mercury input and mercury distribution across the utility industry.

Costs and Conclusions

FETC's mercury control strategy is to shepherd the development of successful control technologies while doing so at reduced costs. And the vast amount of data collected under our mercury program has been instrumental in providing better estimates on the costs of controlling mercury in the utility industry. Using carbon injection under different scenarios as an example, FETC estimates the annual cost for mercury control to be $2.5 to about $6 billion to reduce mercury emissions by about 46 tons—a cost estimate that is about half the estimate of three years ago. Even so, this cost represents a large impact on the utility industry and consumers of electricity: the annual $6 billion incremental cost for mercury control is about 25 percent of the annual cost of as-delivered coal to electric utilities.

Our goal is to reduce mercury emissions from power plants by 90 percent at half of the current estimated costs if mercury regulations are imposed. The FETC program is investigating the development of low cost, highly effective adsorbents; the use of a compact high air-to-cloth ratio fabric filter for higher contact times and reduction of mass transfer limitations of the adsorbents; and the recycling of captured adsorbents and fly ash. These areas have the potential for substantially reducing the cost of control for the utility industry and they can provide for multi-pollutant control, which can contribute to further cost reductions. Large-scale demonstrations are needed to fully evaluate the engineering problems associated with using large amounts of activated carbon as a cost-effective mercury control strategy.

Therefore, EPA, DOE, EPRI, and all others involved in mercury programs, must conduct thorough studies now to make prudent decisions in the future—so that utility customers can have a clean environment and abundant supplies of energy at a fair price.

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Clean Water

FETC Goes With the Flow

As the scenic Youghiogheny River winds down the Western Maryland mountains into Pennsylvania, rafters, kayakers, fishermen, and other outdoor enthusiasts enjoy its beauty, but the depths of the river conceal a serious problem that threatens its fragile biology and poses potential difficulties for residents along her banks.

People have had personal relationships with waterways for generations. The Mississippi River symbolized independence to Mark Twain's Huckleberry Finn. Today, the Yough River—like nearly all waterways throughout the region and country—provides recreational choices and economic opportunities through tourism, business, home construction, and other enterprises. Continued deterioration in water quality threatens recreational uses, endangers wildlife, and holds the potential for contaminating groundwater used by residents.

The ecological threat comes primarily from abandoned underground mines, a legacy from an era of heavy industrial activity that now threatens the natural chemical balance of the river. In addition, the river's own naturally fractured riverbed puts up little resistance to the mine seepage. The natural geology of the river—its fractures—serve as conduits for water to enter mine voids and become polluted or allow the pollution to escape into the river.

The pollution from mine seepage, often visible as yellowish-to-reddish colored water, is produced by pyritic minerals. The problem occurs when these minerals are exposed to the oxygen in a flowing body of water. The minerals are then oxidized and the result is the release of sulfuric acid. (See *Acid Mine Drainage: What Is It?* on page 37.)

FETC's Clean Water Role

Although FETC has focused on developing fossil energy technologies to clean up the environment, we have also conducted research in other areas, such as acid mine drainage (AMD), using biological microorganisms to "eat" the sulfur contained in coal, and using leach-bed techniques to clean contaminants from acid mine runoff.

The Youghiogheny River Project was born when a variety of environmental groups sought FETC's assistance in addressing mine drainage problems in the river. Pulling together a wide variety of resources, FETC created a united front to address regional watersheds—to broaden our experience beyond AMD and to apply short- and long-term solutions to other water quality problems facing the region. The objective is to address the totality of various watersheds—not just AMD—to include other sources of problems such as

industrial, agricultural, and municipal activities.

FETC recently responded to a request from the Federal Emergency Management Association and West Virginia officials from Tucker and Randolph counties to develop a risk assessment strategy that includes effects of floods on ecosystem health. Those two West Virginia counties were hit by three major floods within the past 10 years, resulting in the loss of sewage facilities and setbacks in acid mine drainage control.

As part of the River of Promise Working Group, FETC participated in an effort sponsored by the Department of Interior to coordinate AMD activities on the Cheat River in West Virginia. In addition to FETC, the working group included other federal and state organizations, academic institutions, private companies, and local citizens groups. The group met quarterly to exchange information and coordinate regional resources. As a result of those meetings, the group eventually coordinated eight watershed improvement projects within the past three years.

FETC's campus in South Park Township is partially bordered by segments of the Peters Creek Watershed, which runs through two townships and eventually empties into the Monongahela River. FETC supported an initiative with the neighboring township to create a volunteer citizens group to clean up the watershed. One of the cleanup activists is a 17-year-old who works on the project as part of a requirement to become an Eagle Scout. With assistance from community participants, the scout plans to recruit other scouts and clean up one of the creeks in the watershed within the next five years.

We see our role in the overall watershed effort as coordinator of regional organizations and assets, using our experience in water and soil remediation projects. As Watershed Science and Technology Initiative Coordinator, Jan Wachter, puts it: "FETC's expertise in solving national energy and environmental problems within a cross-cutting and partnering framework serves as an excellent springboard and bridge to working with our stakeholders to improve the region's and Nation's watersheds."

Clean Water: A High-Tech Effort

We attempt to use state-of-the-art technologies to help solve water problems—developing techniques and applying cutting-edge technology to solve an environmental problem, to clean a polluted river.

Sometimes the first problem is just trying to figure out where the pollution is coming from. Traditionally, researchers identified sources of mine drainage by walking along the river bank or drifting downstream in a boat while looking for signs of deteriorated water quality. Today, the use of airborne-based mapping techniques, adapted from the Department of Defense, can be coupled with satellite-based global positioning systems and geologic information systems to locate river pollution sources. These systems can give the exact longitude and latitude of the discharges, thereby pinpointing their location for easy mapping and field trips to the polluted area.

Once the source has been identified, it is usually necessary to control the water flow. Water management is used to prevent contaminated water from entering the river, to direct it toward the treatment area, and to prevent clean water from flowing back into the mine. One of the best ways of preventing contaminated water from entering the river is to lower the groundwater table to reduce the amount of discharge into the riverbed. Multiple wells are drilled into the mine pool to relieve water pressure. This allows the water to flow out of the mine at a point where it can be controlled and directed toward a treatment area—and away from the clean river water.

Sometimes the polluted water actually bubbles up into the stream from underground cracks and fissures. In this case, the stream bottom has to be sealed to prevent the polluted water from entering and the clean water from disappearing down the same fissure. Grouting techniques can be used to seal these fractures in the riverbed. The grout acts just like the grout between bathroom tiles to prevent water from seeping through. Once the polluted water has been segregated, treatment options can be considered.

FETC has investigated *passive treatments*—those that require minimal cost and maintenance, and *active treatments*, those requiring pumps and other machinery to address large amounts of pollution, as well as techniques that offer the benefits of both.

One of these "hybrids" is a DOE-patented system for water treatment. The device uses the force of the flowing water to power the treatment, thus providing the benefit of an active treatment at a low cost. Although the current device needs the fairly large differences in elevation that exist only in the more mountainous coal mining regions, we are attempting to develop one that can be operated using lower water pressures.

Regardless of the treatment technology used, iron is recovered as a gelatinous sludge. Research has shown that this AMD sludge can subsequently be dewatered and transformed into useable cement-like by-products, such as blocks. FETC researchers see dual benefits: improved water quality in rivers and disposal options for sludge, including creation of useable by-products.

A Collaborative Effort

FETC's current Clean Water projects

- FETC is collaborating with Maryland officials to provide geophysical surveys of affected mine sites and provide technical assistance associated with the control of acid drainage from abandoned underground mines.
- FETC is providing technical and project management support to aid the National Park Service in remediating a watershed primarily impacted by abandoned coal mines at the Big South Fork National River and Recreation Area.
- Combining expertise in geology, geochemistry, metallurgy, and mining, FETC and the Western Environmental Technology Office are studying the prospects of removing and recovering heavy metals from waste water in metal mines and smelters.
- FETC and the Pennsylvania Department of Environmental Protection are planning to develop water-powered environmental devices that treat mine drainage at remote sites in the State's anthracite coal fields.
- FETC has begun formalizing an alliance with the U.S. Environmental Protection Agency (EPA) to deal with underground mine pools, watershed modeling, agricultural wastes, and economic analyses. In a project of national interest, the EPA is interested in FETC's work on sulfate reduction bioreactors to apply to the Berkeley Pit Superfund site in Butte, Montana.
- FETC has responded to the U.S. Army Corps of Engineers' request to evaluate mine fire conditions and abatement alternatives on the Corps-developed Fishtrap Lake, where forest fires have exposed and ignited coal seams along the lake.
- Partnerships have always been a hallmark of FETC's business practices, and FETC has facilitated an agreement, called a Memorandum of Understanding, with the nonprofit Canaan Valley Institute to help with watershed management activities throughout the Mid-Atlantic Highlands.
- FETC scientists are working with Department of Transportation officials in Pennsylvania and West Virginia to deal with problems that acidic drainage causes to roadbeds.
- Responding to a request from Preston County, West Virginia, to design a countywide watershed improvement program, FETC helped the county to pursue an AmeriCorps grant that brings together groups to build wetlands, plant trees, monitor streams, and provide information. (See *Expanding FETC's résumé—The Mountain's Promise Program* on page 34.)
- FETC has enacted an interagency agreement with the U.S. Forest Service to conduct geophysical investigations at four sites near Silverton, Colorado, to identify water loss zones in mountain streams, determine the impact of a collapsed mine shaft, and locate acid-producing pyritic material in the flood plain of mountain streams.

The use of these high-tech solutions to solve a regional problem—pollution in a local river—also has national implications. FETC plans to eventually apply the technology to similar problems across the country.

The Youghiogheny River Project, now in its infancy, represents just one of many clean water projects that FETC h as tackled as part of the Administration's new clean water initiative, called the Clean Water Action Plan. (See *The Clean Water Action Plan* on page 36.)

FETC Goes With the Flow

The nature of our business cuts across a variety of energy and environmental interests. We conduct research, but we also manage projects; address environmental, energy, and safety issues; and administer programs associated with fossil energy. In addition, FETC's cross-cutting capabilities have broadened over the years to include clean water initiatives. Using existing resources and in cooperation with other government agencies, FETC has been able to "go with the flow" to extend our expertise to focus on regional and the national water problems.

FETC has been concerned about the regional issue of AMD—an issue that involves about 3,500 miles of seriously affected northern Appalachian streams. Former coal mine sites dot the region from larger suburban communities such as Bethel Park, Pennsylvania, to small, traditional coal mine camp towns like Webster, Pennsylvania. Within FETC's regional Appalachian catchment area, AMD has been the number one water problem. We have been able to provide some regional focus to the problem by sharing long-time experience in AMD characterization, control, and treatment; developing technologies used worldwide to reduce environmental impacts at both active and abandoned mine sites; and making available a database on geoscience and the environment developed for our oil and gas programs.

FETC's Watershed Science and Technology Initiative

As we become more involved in the region's watersheds, we plan to build on the database of information that currently exists and to continue to form partnerships to address clean water issues. By using the programs and technology at our sites in Pittsburgh and Morgantown, we plan to put a major dent in regional watershed problems. We initially plan to identify short- and mid-term projects associated with priority watersheds. As one example, we have been working with the Eastern Mine Drainage Federal Consortium to deal with the continued discharge of AMD from underground mines to the Monongahela River. But we are not limiting our efforts to the Mon Valley area; we will address similar problems identified in each of the two states.

The Vision—a Summary

Jan Wachter summarizes FETC's watershed vision: *Simply stated, FETC's vision in its watershed science and technology initiative is to add technical, scientific, and management value to watershed characterization, remediation, and restoration activities*. FETC has focused its vision toward the future—a vision that begins with a commitment and ends with the certainty that the nation has clean and healthful water,

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Expanding FETC's Role

The Mountain's Promise Program

Comprehensive environmental solutions require the involvement of all those concerned. An inspired coalition of existing grass-roots, private-sector, and government organizations has formed an effective community-based partnership in Preston County, West Virginia.

In 1997, West Virginia Governor Cecil Underwood challenged local community leaders to increase community service as a means of solving problems. FETC suggested to the Preston County Commission that they should apply for federal assistance to help solve specific environmental problems. We also offered FETC's expertise in proposal writing, project management, and understanding of how to form a working group. The commissioners knew Preston County had a problem with acid mine drainage (AMD), and they also knew they needed help in solving this problem. In addition, FETC recognized that the U.S. Environmental Protection Agency is changing how it regulates water quality: from point source to entire watersheds.

The result: The Mountain's Promise Program, a county-wide watershed improvement program.

The Program has already been termed a model—a model for how other communities can solve their own environmental problems by building successful partnerships among concerned citizens; local school system and regional university-level educators; Federal, State, and local governments; regional industry; and local volunteer organizations. FETC has received requests for help in starting similar programs in other counties in West Virginia as well as in neighboring states.

For more than 100 years, surface and underground coal mining was a primary focus of north-central West Virginia industry. The legacy is thousands of acres of disturbed land and hundreds of miles of underground tunnels—all of which have now been abandoned. AMD has rendered more than two-thirds of Preston County's streams orange and unable to support fish. Almost the entire county is within the Cheat Watershed.

The Mountain's Promise Program is officially started. Carl Bauer (left front), Scott Plum (center front), and Randy Harris (right front) are surrounded by AmeriCorps members and dignitaries at the kickoff ceremony in Kingwood, West Virginia.

Under Randy Harris' tutelage, the Preston County Commission successfully applied for an AmeriCorps grant to the West Virginia Commission for National and Community Service. In July 1998, AmeriCorps awarded the County a $147,000 per year renewable grant matched by $35,000 in county funds and $60,000 in partner commitments. The grant is renewable for up to 5 more years.

Mountain's Promise employs 20 AmeriCorps members—six full-time and 14 part-time workers from Preston County and surrounding areas. A full-time director supervises the program. AmeriCorps members pick up litter, plant trees, and try to reverse the effects of AMD. They visit elementary and middle schools and the one high school in the County to help teachers incorporate environmental material into their lesson plans and to organize an Environmental Fair. AmeriCorps members are volunteers who, in return for committing to provide community assistance for specific periods of time, receive a living stipend and an educational award when they finish their commitments.

FETC's work for the Mountain's Promise Program includes a county-wide map of the Cheat Watershed. FETC researchers used specialized mapping software to create a base map that shows roads, streams, and towns in the county. FETC will be training high-school students as well as AmeriCorps members on how to use this base map to locate specific problems and solutions in the watershed, such as locations of sample points, point-source discharges, and remediation constructions. The information can also be transferred to smaller-scale maps of individual tributaries.

FETC has shown one county how to go about solving their environmental problem. As the lead sentence in a recent article in a local newspaper noted, "A new group holds promise for bringing jobs and money into Preston County while cleaning up some of the dirtiest streams in the State."

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A John Denver lyric was the inspiration for the title, **The Mountain's Promise Program**: *Like the music of the mountains and the colors of the rainbow, they're a promise of the future and a blessing for today.*

John Denver, "Rhymes and Reasons" ©copyright 1969, Cherry Lane Music Co.

The Mountain's Promise Program Model

(examples in parentheses)

1. **Identify** the environmental problem. (Over two-thirds of the county streams have acid mine drainage and cannot support fish.)
2. **Pull together** organizations or companies with jurisdiction or interests in the area. (Federal Energy Technology Center, West Virginia University Extension Service, U.S. Office of Surface Mines, Anker Energy, Columbia Natural Resources, National Mine Land Reclamation Center, Friends of the Cheat, Downstream Alliance, Environmental Protection Agency's Appalachian Clean Streams Initiative, W.V. Abandoned Mine Lands Program, Preston County School District)
3. **Form** an oversight community and technical panel from among these organizations and companies. (Environmental Advisory Group)
4. **Identify** the decision-making body (Preston County Commission), and a day-to-day manager of activities. (hired under the AmeriCorps grant)
5. **Devise** a mission statement. *(Provide the mechanisms and resources to allow the community to leverage public- and private-funded activities with volunteer efforts to fulfill the environmental and employment promise of north-central West Virginia)*
6. **Plan** community projects that will correct the environmental problem. (See *Mountain's Promise Projects* on page 36.)
7. **Secure funding** for the program. (AmeriCorps Grant)

Mountain's Promise Projects

Headwater Remediation: Construct small dam-like structures, and place limestone sand behind them to increase the alkaline loading of the streams.
Tree Planting: Plant trees in areas deforested by surface mining or AMD remediation activities.
Monitoring: Collect water, mud, and fish samples for analysis by AmeriCorps members or by technical partners.
Coordinate Environmental Projects: Work with watershed groups and other local volunteer organizations.
Trash Cleanup: Organize and conduct cleanups and construct obstacles to deter future dumping.
Schools: Define specific class projects and work with teachers and students to conduct watershed-related educational projects.
Youth Groups: Plan watershed-related activities with local church youth, scouting, and 4-H groups.

The Clean Water Action Plan

In early 1998, the Administration announced a major clean water initiative, called the Clean Water Action Plan, to celebrate the 25th anniversary of the Clean Water Act. The plan strives to develop new partnerships among environmental groups, governments, tribes, businesses, and the public to clean the Nation's rivers, lakes, and coastal waters.

Considered the most expansive effort to clean the Nation's water since the 1972 Clean Water Act, the new plan seeks to identify regional and national watersheds with the greatest problems, and to provide solutions through collaborative efforts. Those solutions will address public health, attack specific water problems, and provide information to an increasingly concerned public—a public tuned in to the message that one-third of the Nation's rivers, one-half of the estuaries, and one-half of the lakes are unsafe for usual activities.

The federal government established a series of key strategies to carry out the new plan. The first strategy involves enabling watershed assessments, restoration, and pollution prevention and providing grant assistance. The second strategy calls for stronger federal and state standards to improve water quality and protect the health of U.S. citizens nationwide. A third focuses on consolidating resources to mount a united front in water cleanup efforts. And the final strategy aims at informing the public about community water standards and quality through modern communications methods.

The effort is ambitious and the key to adequate progress is pulling together all the resources in a manageable way. FETC is doing just that and has offered its scientists and engineers to lend their expertise—expertise built on years of research in areas such as acid mine drainage and environmental remediation.

Acid Mine Drainage: What Is It?

Streams that flow by mining sites often have a yellow-to-red color, reflective of generations of mine operations that have produced a kind of pollution known as acid mine drainage, or AMD. While mining of various minerals, such as gold or zinc, may cause acid mine drainage, the primary source of AMD in the U.S. is coal mining.

What is AMD? By definition, it is ground or surface water that comes from or flows over or through an area where mining has occurred. AMD occurs when the mineral known as pyrite (iron sulfide) becomes exposed to air and water, resulting in the formation of sulfuric acid and iron hydroxide. Pyrite commonly appears in coal seams and in the rock layers overlying coal seams. AMD formation is commonly present during surface mining when the overlying rocks are broken and removed to mine the coal. AMD can also happen in underground mines when oxygen can freely move to coal seams containing pyrite.

When AMD occurs, the resulting acidity and iron can harm water resources by lowering the pH level of the water and covering the stream bed with iron hydroxide, which is the discoloration sometimes called "yellow boy."

But mine drainage is not always acidic: the drainage can span the range from acidic to neutral to alkaline. In areas having naturally occurring limestone, the acidity can be neutralized. Therefore, to determine whether a mine will create acidic drainage, the coal and rocks can be analyzed to determine the amount of pyrite and neutralizers. According to the Pennsylvania Clean Streams Law amended in 1965, the Pennsylvania Department of Environmental Protection cannot issue a permit for new coal mining when that mining will cause acid mine drainage.

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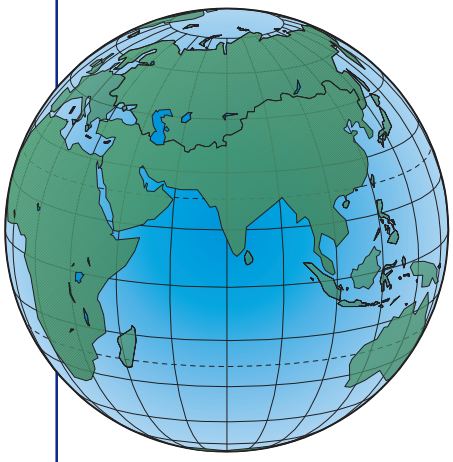
Going Global

India



Think globally; act locally: this "mantra" of the environmental movement says that a cleaner world starts in our own backyards. It also reflects that opportunities to act on a world scale are rare—extending our neighborhood trash pickup worldwide isn't exactly easy.

Rarer still are opportunities for global action that promote business and help a nation raise its standard of living. FETC has been fortunate to have had such an opportunity in the work it has undertaken for the past 15 years in India—the Land of Holy Rivers.

With more than 940 million people in an area one third the size of the United States, India is a large, vibrant, diverse country. Its inhabitants speak Hindi (the national language), English, and 14 other major languages, with hundreds of dialects. Currently, one out of every six people in the world lives in the mountains, deserts, and plains of India. And the population is growing: India is expected to have 1.4 billion people by 2025, and it could overtake China soon after to become the most populous nation on earth.

Accompanying this swelling population is an increase in India's middle class. Some 260 million people are considered middle class in India—about the same number as the entire population of the United States. As this segment of the population grows, consumers will demand more of the energy-using products that we in developed nations take for granted—electric lighting, major appliances, television sets, and the like.

On a per-capita basis, India's annual production of electricity is currently only about 400 kilowatt hours (kWh). This means that right now, India barely produces enough electricity for the average person to light a single 40-watt bulb for a year. India's electricity production lags behind other developing countries, such as China (835 kWh) and Mexico (1,635 kWh), and it's only a fraction of what is produced in developed countries. The United States generates 40 times as much electricity per person as India. Even with this relatively small demand, a gap exists between India's energy production and demand: during normal times, there is a shortfall of 8 percent and at peak times, there's an 11 percent shortfall. To cover the shortfall, power blackouts are regularly scheduled in many parts of the country. At other times, the electrical supply falters or fails, in much the same way as electricity can be momentarily lost during an electrical storm.

To meet increasing demand, the Indian Central Electricity Authority forecasts that India will need to increase its total generating capacity over fourfold in the next 20 years—from its current capacity of about 92,000 megawatts (MW) to about 386,000 MW. This will require an investment of about $16 billion *each year* to install power generation equipment and associated transmission and distribution

equipment. Clearly, India needs to squeeze every kilowatt out of its existing and future power generation plants. It also needs to consider the environmental impacts of a significant increase in power generation, especially if the increased capacity is based on coal.

And in India, most new power plants will undoubtedly be coal-fired. Coal is India's most abundant fossil fuel. It currently fuels some 70 percent of India's electricity production—about 215 million tons of coal were used to produce electricity in 1997-98, and about 400 million tons are expected to be used annually by 2006-07. Contributing to the environmental impact, India's coal is of poor quality. The ash content of Indian coal sometimes exceeds 40 percent. In other words, for every ton of coal burned, about 800 pounds of ash remain. This can add up quickly since a single 210 MW unit burns about 125 tons of coal per hour. Unfortunately, most of this ash ends up in landfills and ash lagoons, which can have an adverse impact on the local ecosystem; only 2 to 3 percent is used productively.

Given this growing demand for electricity, and the lack of fuel options other than coal, the need for highly efficient, environmentally friendly, coal-fired power plants is clear. To help meet this need, FETC—through a series of agreements with the U.S. Agency for International Development (USAID)—has conducted five multi-year projects with Indian companies and organizations since the early 1980s to improve the efficiency and reduce the environmental impact of using coal. These projects have also provided stepping stones for U.S. businesses to enter Indian coal and power-generation markets.

Technologies to Clean India's Coal

The Program for Acceleration of Commercial Energy Research (PACER) illustrates how FETC's work has helped the environment and positioned U.S. businesses to enter an emerging market. Under this recently completed program, two U.S. small businesses—Spectrum Technologies of Schenectady, NY, and CLI Corporation of Canonsburg, PA—were awarded over $3 million by USAID to demonstrate U.S.-developed advanced coal-cleaning technologies at the first private plant in India to clean coal for power plant use. Coal India Ltd., a Government of India company, currently operates two plants that clean power-plant coal. Using the first of these government-owned plants as a baseline, the demonstrated technologies should be able to double the amount of ash removed for the same processing price per ton of raw coal, even with the somewhat higher capital cost figured in.

The private plant will clean 2.5 million tons per year of high-ash Indian coal for Bombay Suburban Electric Supply, one of the few private power companies in India.

The Indian government recently passed a law requiring many new coal-fired power plants—and all new coal-fired plants in urban or "sensitive" areas—to use coal with no more than 34 percent ash content. Since this is virtually unattainable with Indian coal as it comes from the mines, the market for advanced coal-cleaning technologies in India is huge; it has been estimated to be worth more than $4 billion. PACER has helped give U.S. companies an early entry into this market, and U.S. companies are expected to garner at least a 25 percent market share. In addition to the entry of Spectrum Technologies and CLI Corporation into this market through USAID, another U.S. business, Roberts & Schaefer Company, has won two awards to construct commercial coal washeries in India during a solicitation by Coal India Ltd. If U.S.-developed advanced coal-cleaning technologies continue to make their way into Indian power plants, this will be good for India, good for the environment, and good for U.S. businesses.

Reducing Greenhouse Gases

FETC's current work in India though USAID focuses on the Greenhouse Gas Pollution Prevention (GEP) Project. The two main goals of the GEP—pronounced "jeep"—Project are to reduce greenhouse gas emissions per unit of coal-fired electricity produced, and to promote power generation using biomass fuels so less coal-fired power is needed. Reducing emissions of greenhouse gases—which are suspected of contributing to climate change—is vitally important in India because it is currently the fifth largest, and second fastest growing source of greenhouse gas emissions worldwide. If India increases its power generation capacity without improving control of emissions, the environmental impact could be severe.

The GEP Project has two components: Advanced Bagasse Cogeneration (ABC) and Efficient Coal Conversion (ECC). The goal of the ABC component is to work with Indian sugar mills to promote efficient cogeneration (the simultaneous production of electricity and thermal energy). Year-round export of power to the grid could result from supplementing the mills' traditional fuel, bagasse (the pulp remaining from sugar cane after the juice has been extracted), with other biomass fuels, such as cane stems and rice hulls, in higher efficiency boiler systems. Most studies estimate the economic potential of power generation in Indian sugar mills at about 3,500 MW. If this much electricity can be generated through sugar mills, then an equivalent amount of electricity from coal—with its attendant environmental concerns—will *not* need to be generated.

Under the ABC component, nine new or existing sugar mills received almost $1 million each to install new, high-pressure, more-efficient boilers and turbine generators. Before these improvements, the mills generated electricity for their own use, but they exported very little power to the grid. The improvements at these nine demonstration projects have resulted in the addition of about 200 MW to India's power generation capacity. The ABC component of the project also provides free training in the operation and maintenance of new, high-efficiency

Gary Staats, FETC Project Manager, samples India's culture.

FETC/USAID Projects in India

Project Name	Years	Highlights/Accomplishments
Alternative Energy Research and Development (AERD)	1982-1992	Completed the first comprehensive air pollution survey ever performed at an Indian coal-fired power plant. Assisted with the design, erection, and commissioning of two state-of-the-art pilot-scale coal combustion test facilities.
Energy Management Consultancy and Training (EMCAT)	1993-1995	Completed a detailed remaining-life assessment study on a nearly 30-year-old coal-fired power plant. The assessment showed that renovation and modernization of old power plants can be more cost-effective than new plant construction.
Indo-U.S. Coal Preparation and Beneficiation Program	1994-1998	Completed techno-economic studies of coal washing and power plant use of washed coal. Developed model agreements for U.S. companies to operate coal washeries in India. Assisted in formalizing a revolving fund to finance coal beneficiation plants. Organized an Indo-U.S. coal beneficiation workshop.
Program for Acceleration of Commercial Energy Research (PACER)	1987-1997	Demonstrated U.S.-developed advanced coal-cleaning technology at the first private non-coking coal cleaning plant in India. Improved technology should double the amount of ash removed from coal for the same price per ton of raw coal.
Greenhouse Gas Pollution Prevention (GEP)	1995-2000	*Efficient Coal Conversion (ECC) Component:* Will demonstrate U.S. technologies to reduce greenhouse gas and particulate emissions and increase utilization of fly ash from existing coal-fired power plants. *Advanced Bagasse Cogeneration (ABC) Component:* Will promote efficient cogeneration at sugar mills using only biomass fuels with year-round power export to the grid.

cogeneration plants, and it provides cost-shared funds (1) to prepare the documents—called "detail project reports"—needed to apply for bank financing to develop a new cogeneration plant, and (2) to conduct any type of developmental research related to cogeneration, including demonstration of additional biomass fuels besides bagasse.

The primary goal of the ECC component of the project is to reduce greenhouse gas emissions from existing coal-fired power plants in India through demonstration of U.S. technologies that improve efficiency. Advanced technologies for coal-fired power generation and technologies to reduce particulate emissions, increase plant availability, and utilize ash will also be demonstrated. Under this component, a Centre for Power Efficiency and Environmental Protection (CenPEEP) has been established in India by the National Thermal Power Corporation (NTPC), a Government of India company that is India's largest power company and the ninth largest thermal-power generation company in the world. EPRI (formerly the Electric Power Research Institute), supported by the Tennessee Valley Authority (TVA), has been awarded a cooperative agreement for $1.5 million to provide technical assistance on ECC activities, and an interagency agreement has been reached with TVA for up to an additional $1.2 million in technical assistance and training. To date, 12 technical teams from the U.S. have traveled to India and have provided over 3,200 labor hours of training and technical assistance to Indian power plants through CenPEEP. Indian power plant personnel have acquired over 28,000 labor hours of training and assistance from these U.S. experts. Eighteen workshops and training courses have been held, and a CenPEEP newsletter has been created with over 3,000 copies of the initial issue distributed to Indian utility personnel.

One example of a CenPEEP activity is an effort to improve the heat rate (the amount of coal necessary to produce a unit of

electricity) of existing coal-fired power plants in India. After the latest U.S. monitoring and diagnostic instrumentation and equipment for power plant efficiency were demonstrated, the performance of NTPC's Dadri power station—which supplies about half of New Delhi's power—was improved so that coal consumption was reduced by almost 100,000 tons annually, saving the plant over $2.4 million in fuel costs each year. The overall efficiency of this 840 MW plant (four units, each 210 MW) was improved by 1.5 percent. This seemingly small improvement translates into an annual reduction in CO_2 emissions of over 95,000 tons. These results could be replicated at over 130 units of similar size (200 to 210 MW) in India; improvements have already been completed or are underway at seven other Indian power plants with a combined capacity of over 9,100 MW. By attaining similar efficiencies at all coal-fired units in India, an annual reduction of more than 10 million tons of CO_2 emissions may be achievable.

In another example of an ECC activity, a fly ash utilization study was completed by GAI Consultants, Inc., of Monroeville, PA, with support from the University of Pittsburgh. When coal is burned, the ash produced remains in the bottom of the boiler, giving it the name "bottom" ash, or it is captured in the smokestack as "fly" ash. Power plants typically produce much more fly ash than bottom ash, usually about four times as much. Based on this study, two projects demonstrating how fly ash can be used in road construction or as structural fill are underway in the vicinity of the Dadri power plant. Using this ash productively will prevent the environmental problem of disposal in landfills. It will also conserve energy by reducing the demand for typical pavement materials, such as cement and crushed stone, which take energy to produce. It has been estimated, for example, that each ton of fly ash used to replace a ton of cement saves the equivalent of nearly one barrel of oil. By saving energy, the greenhouse gases that would have been produced are avoided.

These two examples show the kind of services that CenPEEP hopes to provide to all Indian utilities on a cost-recovery basis: services in power plant life extension, preventive maintenance, efficiency improvement, environmental monitoring and compliance, and ash utilization.

FETC's continuing involvement in USAID activities in India provides that rare opportunity to simultaneously promote U.S. business, assist a developing nation, and protect the environment. The projects undertaken demonstrate that U.S. technologies can help India meet its growing energy demands with minimal environmental impact. In the process, U.S. businesses gain a share of a growing market. Environmental problems know no boundaries; when clean coal technologies are used worldwide, the whole world benefits. It's global.

Partial funding for the GEP Project comes from the United States' contribution to the pilot phase of the Global Environment Facility (GEF). The GEF is a financial mechanism that provides grant and concessional funds to recipient countries for projects and activities that aim to protect the global environment in four areas: climate change, biological diversity, international waters, and stratospheric ozone. The GEF covers the difference (or "increment") between the costs of a project undertaken with global environmental objectives in mind, and the costs of an alternative project that the country would have implemented in the absence of global environmental concerns. The GEF is jointly implemented by the United Nations Development Programme, the United Nations Environment Programme, and the World Bank.

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"With new technology, much of it being developed in our fossil energy research program, we can ensure that future generations have even cleaner air to breathe while, at the same time, continuing to benefit from the abundance and low cost of our nation's massive coal supplies."

Department of Energy Secretary Bill Richardson in Pittsburgh, Pennsylvania, announcing a new attack on tiny air pollutants called $PM_{2.5}$.

Secretary Richardson Addresses $PM_{2.5}$

While visiting FETC's Pittsburgh site, the Secretary awarded a $2-million contract to a Pittsburgh company, Advanced Technology Systems, Inc., to install a series of four air monitoring stations around the tri-state area to better understand $PM_{2.5}$, tiny particles with a diameter of 2.5 micrometers or less that can be harmful to health. The company will use advanced equipment to collect data and analyze the particles from four sites—two "supersites" located in Pittsburgh and Green County, Pennsylvania, and two "satellite sites" located near Athens, Ohio, and Morgantown, West Virginia.

The monitoring stations will provide data to DOE, the U.S. Environmental Protection Agency (EPA), and various State environmental offices to help determine those sources emitting the most particles so that effective and fair regulations can be established. This clean air initiative responds to revisions in the National Ambient Air Quality Standards legislation, which establishes limits on $PM_{2.5}$ concentrations in the atmosphere and calls for a nationwide network of $PM_{2.5}$ monitoring stations.

When the $PM_{2.5}$ program is fully implemented, about 1,500 monitoring stations will be set up throughout the country. Most of the stations will determine whether regions of the country are complying with the new air standards.

The photograph above shows the $PM_{2.5}$ monitoring station located in the Lawrenceville section of Pittsburgh, Pennsylvania, one of four $PM_{2.5}$ monitoring sites.

Donald L. Bonk
Product Manager, Combustion Systems

Office of Power Systems Product Management

Burning Animal Waste

Better for the Environment, Safer for Humans

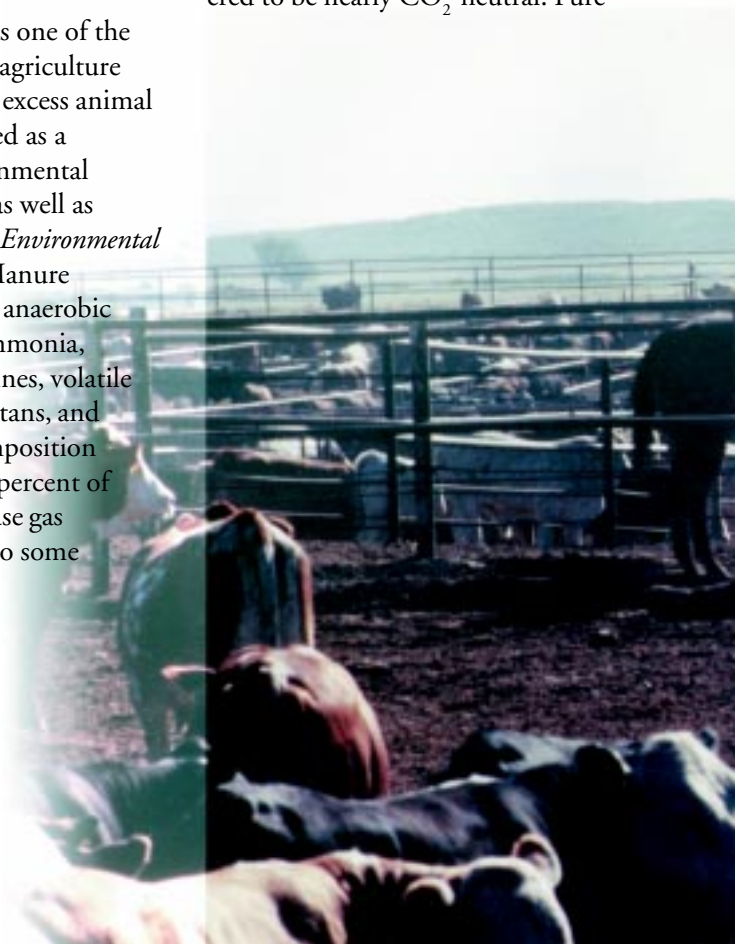
Total combustion of animal wastes is one of the best ways to use livestock and poultry manure while reducing water and air quality problems and transmission of certain disease organisms. And treated animal waste can be readily combusted in combination with a fossil fuel.

We are a meat and poultry society. We consume ever increasing amounts, resulting in large volumes of animal waste: estimates place U.S. poultry litter and livestock manure at over 110 million dry tons per year (equivalent to about 100 million cubic meters). Conventional disposal methods use animal waste as a fertilizer. These methods require proper land application at agronomic rates (i.e., matching soil/plant requirements) and soil management to ensure beneficial use and watershed protection. And without proper care, there are potential health consequences. (See *Health Consequences of Animal Waste Disposal* on page 46.)

Although the U.S. has one of the most efficient animal agriculture systems in the world, excess animal waste (not sold or used as a fertilizer) is an environmental problem in the U.S. as well as abroad. (See *Reducing Environmental Effects* on page 46.) Manure decomposition under anaerobic conditions releases ammonia, hydrogen sulfide, amines, volatile organic acids, mercaptans, and esters. Manure decomposition accounts for about 5 percent of annual U.S. greenhouse gas emissions according to some reports.

One of FETC's newer initiatives is a bioprocessing program, promoted by Dr. Suellen Van Ooteghem who began work at FETC in 1990. We are researching three scenarios that might be used for combustion or gasification of biomass, including animal waste: direct combustion, combustion of a biomass mixture with coal-fired fluidized-bed by-products, and cofiring biomass with coal.

Biomass is agricultural and forest products or residues derived from living plants, landfill gas, and animal wastes. Biomass is renewable and since it absorbs CO_2, the entire process of growing, burning, and regrowing, biomass is considered to be nearly CO_2-neutral. Pure



biomass firing has several drawbacks, although it has been successfully demonstrated abroad. (See *United Kingdom Burns Poultry Waste*.) Its relatively low heating value, high moisture, and low density mean that it can only be transported for short distances. Some types of biomass can also be quite variable in chemical and physical properties. The net cost of electricity from most pure biomass plants is usually quite high.

Cofiring or reburning biomass with coal in large utility boilers is an attractive option: up to 5 percent (or about 20 million tons) of the total U.S. power plant emissions of CO_2 could be mitigated through biomass cofiring. Cofiring also reduces SO_2 and NO_X emissions.

FETC recently signed a cooperative research and development agreement (CRADA) with several organizations including Texas A&M University to test various manure samples in our pilot-scale combustion and environmental research facility (CERF). An industry group including the Texas Cattle Feeders Association is also supporting the project. Fuel handling/processing and relevant environmental safety and health issues will be assessed. The CRADA will enable Southwestern Public Service Company to consider whether the technology would enable the company to conduct a manure cofiring demonstration project at one of its coal-fired generating stations located in west Texas.

Using animal waste as a fuel can eliminate its use in products that might be hazardous to human health, and can also reduce the need for other fuels. Cofiring animal wastes would help reduce greenhouse gas emissions and lower power-plant CO_2, NO_X, and SO_2 emissions. FETC's bioprocessing program is part of our search for environmental solutions, but could also lead to energy solutions.

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United Kingdom Burns Poultry Waste

The United Kingdom has had considerable success in burning poultry waste directly, with no pretreatment. In the last decade, three plants (1992—12.7 MW plant in Eye, Suffolk; 1993—13.5 MW plant in Glanford, Flixborough; and 1996—38.5 MW plant in Thetford, Norfolk) use fluidized-bed technology to burn the waste directly. Poultry waste is high in calcium and nitrogen containing urea. British experts claim that because of this, direct combustion of waste at these sites is able to control NO_X and SO_2. In addition, the by-product sterile ash is an excellent fertilizer: high quality, odorless, and potash-rich.

Health Consequences of Animal Waste Disposal

Animal waste in the U.S. is currently disposed of in two ways: the vast majority is used as a fertilizer; in some cases, poultry litter is used as an additive to animal feeds. Both methods present potential biological risks if the waste is improperly managed.

Harm to a watershed results when the amount of animal waste applied as fertilizer exceeds what can be absorbed by the soil, utilized by the plants, or mitigated by a soil/plant filter system. Unabsorbed runoff from over-fertilized pastures or cropland increases the nutrient content of the water, and can cause an increase in the microorganism population in the water. One particularly serious consequence of watershed runoff enrichment is the microorganism *Pfisteria*—which kills fish and can cause severe mental impairment in humans. *Pfisteria* is believed to have had a definably negative impact on the Chesapeake Bay area. One positive note: the damage caused to humans as well as the environment by *Pfisteria* is reversible. . .

Problems may also result when animal wastes are used as additives to animal feeds. The wastes contain several animal and human pathogens. Most of these pathogens can be killed by conventional sterilization methods during processing, such as composting, ensilage, or deep-stacking. However some are more resistant to conventional sterilization techniques.

Probably the safest way of utilizing animal wastes in a manner that prevents transmission of disease organisms is to dispose of wastes in a fashion that removes them entirely from the food chain. Total combustion or gasification, which reduce the entire mass to a sterile ash, is an answer.

Reducing Environmental Effects

The Netherlands has about 15 million people (about 8 million in Georgia), living in an area about a fourth the size of Georgia. They share the land with a huge animal population—4.7 million cattle, 13.4 million pigs, 44 million laying hens, 41 million broilers, and 1.7 million sheep. These animals produce three to four times more manure than is needed to fertilize the country. A 500-sow farm producing 20 piglets per sow each year that are fed to slaughter weight produces the same effluent as a town of 25,000 people.

Animal agriculture is critical to their national economy. The Dutch have developed the most stringent manure management regulations in the world as part of their effort to clean their river and air resources. New regulations financially penalize polluters while rewarding innovators who find ways to market manure abroad.

A wheel loader collects cattle feedlot manure, which accumulates at the rate of about 2 tons per animal per year.

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